Climate change in developing countries

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An overview of study results from the Netherlands Climate Change Studies Assistance Programme

M.A. van Drunen, R. Lasage and C. Dorlands (eds.)

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Preface

The Netherlands recognises the need to assist developing countries, not only to comply with its own obligations under the Framework Convention on Climate Change (UNFCCC) but also to enable these countries to develop effective strategies to mitigate climate change and adapt to the adverse effects thereof. Therefore, the Netherlands Climate Change Studies Assistance Programme (NCCSAP) was launched in 1996. The first phase of the NCCSAP is almost finished and the second phase, which has slightly different objectives, has already started.

The Institute for Environmental Studies (IVM), which manages NCCSAP-I, took the initiative to compile this book. It intends to present an overview of the most interesting results of the climate studies carried out in the countries involved. Furthermore it presents a critical evaluation of the methodologies and approaches, and recommendations for future studies about climate change in developing countries. It does not pretend to be a summary of all NCCSAP studies; it rather gives the reader an impression of the work that has been carried out in the last eight years within the programme.

This book is meant for everyone who is involved in climate related projects in developing countries. Both researchers and policymaker can benefit from the experiences and evaluations of the NCCSAP studies. Subjects dealt with do not only include impact studies, but also vulnerability and adaptation, mitigation, and climate related policy. More about NCCSAP, in particular about the second phase, can be found on www.nlcap.org.

In line with the objectives of the NCCSAP, the core part of this book was written by the project members in the developing countries themselves. The editors thank all the authors, of whom several were having quite different jobs by the time they were writing their contribution. Also the technical consultants played an essential role, especially Jan Verhagen, Nico van der Linden, Marcel Rozemeijer and Arjan van der Weck have put tremendous efforts in this book.

The NCCSAP would not have existed without the late Jan Feenstra. He did not only invent the impossible acronym NCCSAP, but he was also involved in the methodology development for climate impact and adaptation studies, and for the organisational structure of the programme. In the mid nineties he managed the programme, and he travelled the world to make sure that all studies went well.

Finally, the editors thank the Netherlands Ministry of Foreign Affairs / Directorate-General for International Cooperation (DGIS) that recognised the importance of climate change for developing countries and decided to initiate the NCCSAP. One of the NCCSAP products is this book.

February 2005

Michiel van Drunen, Manager NCCSAP-I

1. Introduction and NCCSAP methodology

1.1 Introduction

The Netherlands recognises the need to assist developing countries and countries with economies in transition, not only to comply with its own obligations under the Framework Convention on Climate Change (UNFCCC) but also to enable these countries to develop effective strategies to mitigate climate change and adapt to the adverse effects thereof. The Netherlands Climate Change Studies Assistance Programme (NCCSAP) was launched in 1996. This programme aims to help developing countries to prepare their National Communications and to undertake capacity building, education and training activities (VROM, 2001).

NCCSAP was preceded by four coastal zone management studies in Bangladesh, Egypt, Nicaragua, and Vietnam. These studies focused on the effects of sea level rise in coastal areas, possible adaptation options and capacity building. The Coastal Zone Management Centre in The Hague managed these studies. In this book the main results of the studies in Egypt and Vietnam are summarised in Chapter 2.

NCCSAP includes two phases and in this book, only the first phase is described. In total thirteen countries participated in the programme and at the time of writing this book (summer 2004) only the studies in Bhutan were not completed yet. The second phase started in 2004 with a slightly different focus and partly different countries.

The NCCSAP-I studies in the countries resulted in many reports considering climate change issues for each study in each country. Existing information was summarised, new information was generated and information gaps were identified. Among these reports are National Communications, National Action Plans and emission inventories, mitigation studies and sectoral impact and adaptation studies. Generally, the sectoral reports and the policy documents had a good to excellent quality. The policy documents prepared were important to fulfil the commitments to the UNFCCC and to include climate change issues into existing plans for sustainable development in the countries.

This book provides a comprehensive information source on NCCSAP and describes the achievements and experiences in the countries involved. We are hoping that it also serves as an invaluable source of information to climate change experts and policy makers, as well as DGIS and other donors active in the context of the UNFCCC. It does not only present summaries of the studies but also the experiences and lessons learned from the NCCSAP. Many detailed reports have been prepared in the national language of the countries participating and only few scientists published their work in international journals thus far. Therefore, this book also aims to provide valuable input to the IPCC Fourth Assessment Report.

The book covers emission inventories, mitigation and adaptation, but the emphasis is on adaptation. This is in line with the recent developments in the UNFCCC, where adaptation, sustainable development and the links between adaptation and poverty alleviation are getting higher priority and new funds for adaptation are created. Additionally new methods and guidelines for adaptation assessment with a focus on policy development, livelihood systems and poverty are currently being developed and pilot studies and projects adaptation are being started, e.g. in NCCSAP-II. Here, we present the state of the assessment methodologies and policies in the 1990s and it also describe possible next steps. The next section describes an overview of the book contents.

Content

This book includes the following chapters:

1. Introduction and methodology
2. Country experiences and highlights
3. Cross country syntheses
4. Evaluation, lessons learned and outlook

The remainder of Chapter 1 provides a general introduction to the NCCSAP. It also provides summaries of the methodologies used in the studies

Chapter 2 is the core of the book. Here, representatives of the countries have summarised one of their studies and reflected on the strengths and weaknesses of the approach they had adopted.

Chapter 3 presents a cross-country synthesis for each of the sectors assessed in the countries. It also provides a cross-country analysis of the National Communications.

Chapter 4 will evaluate the activities in the Programme in terms of content and process. Topics addressed include capacity building in the participating countries, co-ordination in the countries and the programme management, scientific quality of studies, policy relevance of activities, contribution to climate policy development, contribution to awareness raising, donor activities and policy, etc. Experiences and lessons learned will be identified and discussed. Furthermore, recommendations for future activities will be discussed.

Authors

The authors of the book are the researchers and policymakers who were actually involved in the studies. The core of this book, Chapter 2, was written by the project manager or another senior researchers of the country concerned. Chapters 1, 2 and 3 were written by the consultants who assisted the local researchers by training, visits and backstopping. The editors were involved in the NCCSAP project management. At each section the authors are indicated, unless the editorial team wrote it.

1.2 Approach NCCSAP phase 1

1.2.1 Objectives

The NCCSAP is an initiative of the Netherlands Ministry of Foreign Affairs, Directorate-General for International Cooperation (DGIS), and started in 1996. The objectives of the first phase of the programme were (Van Drunen and Dorland, 2000):

- To enable developing countries to implement commitments under the Framework Convention on Climate Change;
- To create a greater awareness of climate change issues; and

- To increase the involvement of policy makers, scientists and the general public.

The Programme supported the responsible ministry, mostly the Ministry of Environment, to initiate climate change studies that were carried out by appropriate scientific institutions. In 2002 the second phase, which is not treated here, started with different objectives (ETC International, 2004).

Based on the conclusion of the International Panel on Climate Change (McCarthy et al., 2001), it is expected that the impacts of climate change will be most severe in developing countries and thereby may hamper sustainable development and could lead to acute food shortage, poverty and health hazards. The NCCSAP provided opportunities to carry out in-depth climate change impact and adaptation studies. The scope of the studies depended on national needs, priorities, experiences and expertise.

It was the objective that the results of the climate change studies would find their way into the national sustainable development plans, environmental action plans and the National Communications to the UNFCCC of the countries participating. The studies also assisted the national institutes and authorities in strengthening their institutional roles and responsibilities by improving the public awareness on climate change issues.

A prerequisite was that the studies were carried out by institutions and scientists of the participating countries themselves to ensure capacity building and ownership. The national study teams were assisted by international consultants for each specific sector of the climate change studies.

1.2.2 Responsibilities

The Institute for Environmental Studies (IVM) was contracted by DGIS to manage the first phase of the NCCSAP in co-operation with the Netherlands Coastal Zone Management Centre (CZMC). The following countries participated: Bolivia, Bhutan, Colombia, Costa Rica, Ecuador, Ghana, Kazakhstan, Mali, Mongolia, Senegal, Suriname, Yemen and Zimbabwe. The Ministry of Foreign Affairs (Directorate-General for International Cooperation (DGIS)) did the selection of countries.

The managing institute (IVM or CZMC) contracted the responsible ministry. The local ministry appointed a *national focal point co-ordinator* who was responsible for the management of all studies in a country. This co-ordinator was often involved in the studies, but he or she also subcontracted other institutes in the country. The focal-point co-ordinator frequently reported the progress of the studies and the expenditures of the studies.

The studies in each country started with a mission: experts from IVM and/or CZMC visited the country to assist the preparation of the project proposal or workplan. The philosophy behind these missions is that they gave the project a good start: it became clear what needed to be done and who was responsible for the activities agreed upon.

After formal inclusion in the NCCSAP by the Ministry of Foreign Affairs, the national focal point elaborated a detailed plan of operations, in close co-operation with the management of the programme and the international consultants. This contained the organisational framework of the country study, project descriptions, terms of references, workplans and budgets.

1.2.3 The studies

In each country, the studies were carried out by local specialists who were assisted by international consultants. The consultants actively supported the local researchers during visits, organised training sessions and seminars, assisted the studies through e-mail contacts and reviewed draft documents. In some cases local experts were sent to specific trainings or workshops. Table 1.1 gives an overview of the studies per country.

Many of the studies were closely related. For instance, before effective mitigation measures can be formulated, an emission inventory must be carried out, and to formulate adaptation options in agriculture, economic and climate scenarios, and water resources data are needed. This is schematically shown in Figure 1.1.

Because IVM was closely involved in the handbooks on inventories (Houghton *et al*., 1997) and on vulnerability and adaptation (Feenstra *et al.*, 1998), and because of its experience in former studies, it was able to provide the focal points with technical, practical and scientific suggestions and methodologies.

The country studies consisted besides the technical, sectoral studies of two or three national workshops where scientists, policy makers, and representatives of NGOs and the press meet to exchange information regarding the set up of the studies and the results, and to discuss the implications for the national policy. In this way, not only policy makers and scientists are informed about climate change issues, but also the general public and other stakeholders.

Additional to the national workshops, the programme provided regional workshops (e.g. the workshop in Latin America with Bolivia, Costa Rica, Ecuador and Suriname) and bilateral meetings between countries. IVM, the US Country Study Program, UNDP, UNEP and the Japanese government organised the international workshop ‘National assessment results of climate change: impacts and responses’ in Costa Rica on March 25-28, 1998. Representatives from most countries participated in this workshop.

Table 1.1 Overview of studies in the NCCSAP.

	GHG emissions		Vulnerability and adaptation				Policy
Country	Emission Inventory	Mitigation	Agriculture	Forestry Natural areas	Coastal zones	Water resources	National Communication
Bhutan			x			x	
Bolivia	x	x	x	x		x	x
Colombia					x		
Costa Rica			x	x	x		x
Ecuador					x	x	
Ghana					x	x	x
Kazakhstan	x			x#	x		
Mali			x			x	
Mongolia		x	x			x+	x
Senegal			x		x		x
Suriname	x				x	x	
Yemen		x	x			x	x
Zimbabwe		x	x				

The study concerned mudflows and avalanches.
+ The water resources study was not formally included.

In the following sections we describe the methodologies followed in the sectors indicated in Table 1.1.

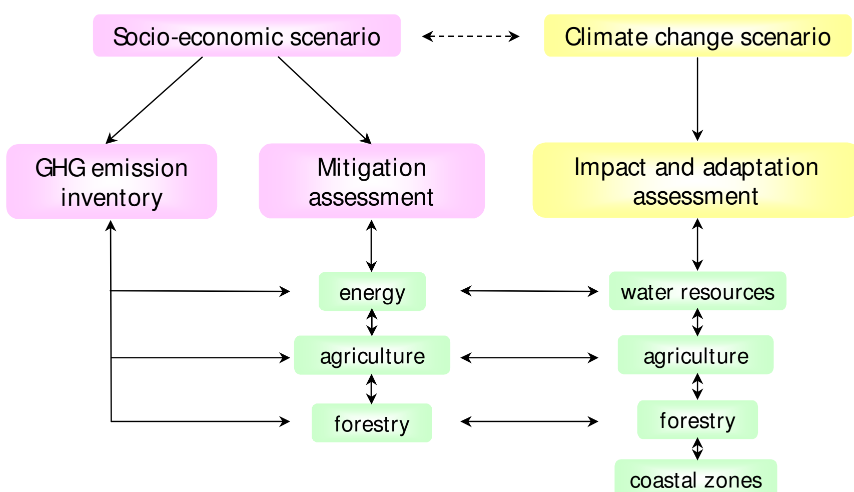

Figure 1.1 Interdependence of climate change study results.

1.3 Methodology for emission inventories

Michiel van Drunen[1]

1.3.1 Policy background

Greenhouse gas emission inventories play a key role in the United Nations Framework Convention on Climate Change (UNFCCC). Since the UNFCCC aims to stabilise greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic (human-induced) interference with the climate system, information is required about emissions of greenhouse gases and also the trends in these emissions. Therefore, 'Each non-Annex I Party shall […] communicate to the Conference of the Parties a national inventory of anthropogenic emissions by sources and removals by sinks of all greenhouse gases (GHGs) not controlled by the Montreal Protocol, to the extent its capacities permit […]. Non-Annex I Parties should use the Revised 1996 Intergovernmental Panel on Climate Change (IPCC) Guidelines for National Greenhouse Gas Inventories, hereinafter referred to as the IPCC Guidelines, for estimating and reporting their national GHG inventories' (UNFCCC, 2003).

Hence, where Annex I countries (the developed countries) must provide annual reports, Non-Annex I countries must report 'to the extent their capacities permit' reports on their emissions. Emission data are published the website of the UNFCCC (unfccc.int). All countries in the NCCSAP are Non-Annex I countries.

1.3.2 Approach

Emissions inventories were carried out in Bolivia, Kazakhstan and Suriname. As obliged by the UNFCCC, all used the revised 1996 IPCC guidelines (Houghton *et al.*, 1997). The IPCC Guidelines were first accepted in 1994 and published in 1995. The UNFCCC Third Conference of Parties (COP3) held in 1997 in Kyoto reaffirmed that the Revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories should be used as 'methodologies for estimating anthropogenic emissions by sources and removals by sinks of greenhouse gases' in calculation of legally-binding targets during the first commitment period.

The gases covered in the Guidelines are the direct greenhouse gases, carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O), the indirect greenhouse gases carbon monoxide (CO), oxides of nitrogen (NO_X), nonmethane volatile organic compounds (NMVOCs), halocarbons (HFCs, PFCs) sulphur hexafluoride (SF_6), and sulphur dioxide (SO_2). Halogenated species (i.e. chlorofluorocarbons (CFCs), hydro-chlorofluorocarbon 22 (HCFC-22), the halons, methyl chloroform and carbon tetrachloride) are not included because of parallel reporting requirements of countries in compliance with commitments under the Montreal Protocol.

The calculation of CO_2 emissions from fuel combustion may be done at three different levels referred to as Tiers 1, 2 and 3 in the IPCC Guidelines. Tier 1 methods, as used in

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the studies described here, concentrate on estimating the emissions from the carbon content of fuels supplied to the country as a whole (the Reference Approach, sometimes referred to as 'top-down') or to the main fuel combustion activities (called Emissions by Source Categories or 'bottom up').

The reference approach

Carbon dioxide emissions are produced when carbon-based fuels are burned. National emissions estimates are made based on amounts of fuels used and the carbon content of fuels. An accurate estimation of national CO_2 emissions by accounting for the carbon in fuels supplied to the economy can be made from the supply of fuels.

Accounting for carbon is based mainly on the supply of primary fuels (i.e. fuels which are found in nature such as coal, crude oil, natural gas) and the net quantities of secondary fuels (e.g. gasoline and lubricants) brought into the country. To calculate supply of fuels to the country the following data for each fuel and year chosen are required (Houghton et al, 1997):

- The amounts of primary fuels produced;
- The amounts of primary and secondary fuels imported;
- The amounts of primary and secondary fuels exported;
- The amounts of fuel used for international marine and aviation bunkers; and
- The net increases or decreases in stocks of the fuels.

Emissions by source categories

A sectoral breakdown of national CO_2 emissions using the defined IPCC source categories is needed for monitoring and abatement policy discussions. The IPCC Reference Approach provides a rapid estimate of the total CO_2 emissions from fuels supplied to the country but it does not break down the emissions by sector. The development of a Tier 1 method giving non-CO_2 emissions from fuel combustion by sector has been extended to CO_2 so that sectoral information can be obtained simply for this gas (Houghton et al, 1997).

The following sectors are considered: Energy, Industrial processes, Solvents and other product use, Agriculture, Land use change and forestry, and Waste. Crucial in the emission estimations are *emission factors*, which link the activity data (e.g. production data in tons or kWh) to the greenhouse gas emissions. Although the IPCC provides default emission factors, these tend to vary from country to country because they heavily depend on the technologies used and the specific conditions under which they are operated.

Reporting

Documentation standards are necessary to ensure transparency of national inventories and hence to allow the inventory to be reviewed. Therefore, one of the three Guideline workbooks is completely devoted to reporting instructions (Houghton et al, 1997). The most important output tables include the GHG emissions by sector and the total emissions by gas type (CO_2, CH_4, etc.). In several output tables the emissions of the non-CO_2 gases are expressed in so called CO_2 equivalents (CO_2e), i.e. the emissions are multiplied by the global warming potential (GWP) of the GHG considered. By definition the GWP of CO_2 is 1. The GWP of methane and nitrous oxide are 21 and 310, respectively (Houghton *et al*., 1997).

1.3.3 Emission inventories in the NCCSAP

In Dorland *et al.* (2001) an overview was presented on the approach and the results of the inventories. Below, we have summarised the methodological approaches in the countries where emission inventories were carried out within the NCCSAP framework.

Bolivia

The Bolivian inventory of GHG emissions has been conducted in accordance with the 1996 revised IPCC guidelines. Unlike the other inventories, Module 3 - Use of solvents and other products, has been included.

For most but not all sectors, IPCC default emission factors were applied where necessary. For deforestation a more suitable, local value has been used. The report has a specific section on uncertainty, in which the uncertainty in the CO_2 emission figure for deforestation is estimated to be 35%. In view of the huge contribution of this particular emission source, further research is needed to get a clearer view on what the exact magnitude of the deforestation-related CO_2 emission in Bolivia is.

Kazakhstan

The revised IPCC guidelines of 1996 were used as the methodological basis. In some cases the IPCC methodology was complemented to reflect national circumstances and/or data availability. The GHG emission inventory is divided into six categories, but solvent and other product use was not included because of a lack of available data.

Conversion Factors to calculate CO_2 emissions were taken mostly from local literature sources. The main limitations in the studied inventory, however, are the lack of verified local emission factors, particularly for non-CO_2 emissions. Another limitation of the study results from activities for which neither a local nor an IPCC emission factor exists. Finally, lack of data and high aggregation levels for certain data form another limitation of the study.

Suriname

IPCC default values for fuel type and combustion efficiency were used for the calculation of CO_2 emissions. Solvent and other product use was omitted because of lack of available data. Many other data gaps were identified. The only industry that was reasonably accurately described was the aluminium industry. Only default values were available for the agricultural and the waste sectors and detailed information on land use was not available.

In the report, no attempt was made to compare CO_2 to other GHG emissions. Neither was an attempt made to address uncertainties, but considering the data gaps mentioned and the frequent use of non-area specific default values, the uncertainty forces one to be very careful in drawing any definite conclusions from the figures presented.

1.4 Methodology for mitigation assessment in the energy sector

Nico van der Linden[2] and Jan-Willem Martens[3]

1.4.1 Policy background

The UNFCCC (United Nations, 1992) does not oblige non-Annex I countries (developing countries) to mitigate their greenhouse gas emissions. However, Article 4.5 states 'The developed country Parties and other developed Parties included in Annex II shall take all practicable steps to promote, facilitate and finance, as appropriate, the transfer of, or access to, environmentally sound technologies and know-how to other Parties, particularly developing country Parties, to enable them to implement the provisions of the Convention. In this process, the developed country Parties shall support the development and enhancement of endogenous capacities and technologies of developing country Parties. Other Parties and organizations in a position to do so may also assist in facilitating the transfer of such technologies.'

The Clean Development Mechanism (CDM) was established under Article 12 of the Kyoto Protocol. It is the only flexibility mechanism in the Kyoto Protocol that involves non-Annex I countries. Activities that reduce emissions in non-Annex I countries can result in Certified Emission Reductions (CERs), which may be transferred to Annex I countries. For the countries (or businesses) buying the emission rights, using the CDM offers a clear advantage. When the price of the emission rights is lower than the costs associated with internal or on-site emission reductions, buying credits lowers the overall costs of compliance.

To the investor in CDM projects, the opportunity to sell credits offers an extra source of revenue above the normal project revenues, e.g., for selling electricity. This will increase the financial viability of the project. What is often very important for investments in developing countries is that part of the revenue from the project will come in hard currency and from a buyer with a good reputation (such as the World Bank, a European government or a private company). The prospect of this revenue source can help to promote other financing for the project. For most project types, such as renewable energy projects, the carbon revenues will cover only 5 to 15% of the investment costs. For methane emission reduction projects, the carbon revenues can cover more than half the costs of the project. This difference in extra return can have an effect on the types of project that are developed under the CDM. The CDM is already operational. Under guidance of the CDM Executive Board procedures have been developed and the first projects are ready for approval.

Perhaps the most important benefit provided by CDM for host countries is that they serve to attract foreign investments in low-emission technologies. Both the direct investments and the resulting improvements in efficiency have a positive contribution to the economy and can lead to more employment. Another benefit is that CDM projects often also reduce other pollution in the host country besides GHG emissions, such as local air pollution. For example, a waste management project reduces methane emissions, but also reduces odours around the landfill and reduces ground water pollution.

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1.4.2 Approach in the NCCSAP

Introduction

A mitigation assessment involves an analysis of costs, benefits and reduction potential of options that can be used to reduce greenhouse gas (GHG) emissions. These options may either reduce the amount of GHG emissions or increase the storage of carbon (sequestration). In the NCCSAP Phase I study only the former type of options have been taken into account.

In principal, two approaches can be adopted for mitigation assessment: the top-down approach and the bottom-up approach. The top-down approach starts at the national level and takes into account the interactions between the energy sector and the other economic sectors. The approach involves an analysis of macro variables such as sectoral growth rates and energy efficiency improvements achieved in the past to estimate the emission reduction potential. The bottom-up approach, on the other hand, focuses on individual technologies and attempts to estimate the costs and reduction potential of these technologies. This approach results in a detailed list of concrete reduction options but no interactions with other economic sectors are taken into account. In the NCCSAP Phase I study the bottom-up approach has been adopted for mitigation assessment to be able to assess in detail the impact on GHG emission reduction of individual technological options.

A mitigation assessment consists of the following key components:

1. Development of a national greenhouse gas emissions inventory;
2. Identification of suitable emission reduction options;
3. Assessment of costs and GHG reduction potential of options;
4. Design of aggregated cost abatement curve;
5. Barrier analysis;
6. Strategy formulation.

In the framework of the NCCSAP phase I study, assistance in mitigation assessment has been provided to the mitigation teams of Bolivia, Yemen, Zimbabwe (see also Section 2.14) and Mongolia. In Bolivia and Yemen the focus of the assistance was on the assessment of costs and GHG reduction potential of identified emission reduction options. This involved training on the Long Range Energy Alternative (LEAP) model and the development of a LEAP version that could be used to evaluate the identified emission reduction options. For Zimbabwe and Mongolia these activities were already completed in the framework of other programmes and the assistance focused on barrier analysis and strategy formulation.

Development of national emission inventory

In order to get insight into the potential for mitigating greenhouse gases and what costs are necessary to realise this potential it necessary to have a national emission inventory (see also Section 1.3). Based on the emission invforestryentory, an identification can be

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made where existing GHG emitting sources could be replaced with technologies that use less energy per unit of output.

Identification of emission reduction options

Potential options to reduce GHG emissions can be divided into two broad categories: technological and non-technological options. The technological options can be further divided into options that save energy by improving the efficiency of the process and options aimed at a switch to a cleaner fuel. Non-technological options attempt to influence the level of energy consumption of people by providing financial incentives (tax, subsidy) or by enhancing the awareness with regard to environmental issues. In this step, experts on the various economic sectors are asked to identify potential emission reduction options that will be included in the mitigation assessment.

Assessment of costs and GHG reduction potential

The criterion used ranking the identified options is the net costs (benefits minus costs) per ton CO_2 reduction, which is defined as the ratio of the total net costs of an option divided by the total emission reduction generated by the option.

Cost-benefit analysis is applied to estimate the net costs and involves a systematic comparison of all costs and benefits of a reduction option from a national point of view. Costs include investment costs, and operation and maintenance costs of the emission reduction option. Benefits include the reduction in expenditure on fuels due to a more efficient technology and the benefits related to a reduction of greenhouse gases. Because the latter type of benefits cannot be properly monetised, cost-benefit analysis for mitigation assessment reduces to cost-effectiveness analysis, i.e. the analysis of achieving the stated objective in the least cost manner. The cost effectiveness is an important criterion in a comparison of the options and is determined by dividing the present value of the net costs by the emission reduction. For some options the net costs are negative (benefits exceed costs), indicating that the end user will financially benefit if the option is implemented. There could, however, be several reasons why these ‘win-win’ options are not taken spontaneously, e.g. because option requires large investments, or because of lack of knowledge.

The total emission reduction of options can be estimated by a comparison of baseline and mitigation scenario. A baseline scenario describes the future situation in which no policies or programmes will be implemented to reduce GHG emissions. A base line scenario is not simply an extrapolation of past trends, but it also includes autonomous developments that will occur even without policy interventions. Because it is extremely difficult to predict future economic developments, usually alternative baseline scenarios are developed reflecting different assumptions on, amongst others, future economic growth (low, medium, high).

A mitigation scenario describes the future situation based on the assumption that policy options to reduce GHG emissions are implemented. These options may include technological options and non-technological options and several mitigation scenarios can be developed to assess the impact of individual options. LEAP has been used as a tool to develop baseline and mitigation scenarios in Bolivia and Yemen. LEAP is a technology based accounting model that enables the analyst to store the collected data in a structured and clear manner and to quickly quantify the effects of mitigation options.

Design of an aggregated cost abatement curve

The CO_2 abatement costs curve provides a ranking of individual reduction options based on their net cost effectiveness. This curve shows the relationship between net abatement costs per ton CO_2 and the total quantity of the emission reduction. In some cases, the net abatement cost curve starts at negative values for net costs per unit reflecting the fact that some of the options have marginal net benefits.

Figure 1.2 shows an example of an aggregated cost abatement curve. It depicts the projected CO_2 cost abatement curve for all non-Annex I countries for options in the unit cost range of -50 to +50 US$/ton CO_2 equivalents. The curve is based on an inventory of options in 24 non-Annex I countries to reduce GHG emissions[4], and an extrapolation of the projected aggregated CO_2 abatement cost curve of the 24 countries to the remaining non-Annex I countries.

The total annual GHG emissions abatement potential in the non-Annex countries in the first budget period (2008-2012) at unit costs up to 50 US$/t CO_2 has been projected at approximately 2.25 Gt CO_2 equivalents. Most of this potential is projected to be achievable at quite low costs. Up to 1.6 Gt/year appears feasible at costs of US$ 6/ton or lower.

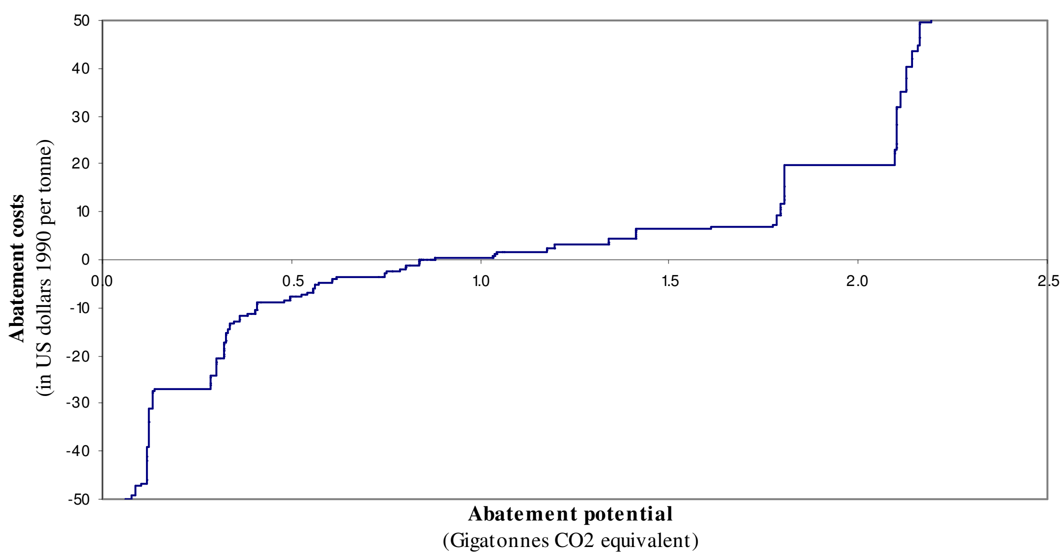

Figure 1.2 The projected CO_2 abatement costs for all non-Annex I countries.

4 For a more detailed description of how the cost curve has been developed and an overview of the limitations of the curve see: Potential and Costs of clean development mechanism options in the energy sector; Inventory of options in non-Annex I countries to reduce GHG emissions; ECN-C-99-095.

Barrier analysis

The mitigation analysis identifies and evaluates emission reduction options. However, existing barriers could prevent the implementation of the best options in terms of cost-effectiveness. This obviously is the case for options with negative net costs. Implementation of these ‘win-win’ options can be justified on pure economic grounds. However, one should consider carefully *why* these options are not implemented and whether the estimate of the costs might neglect implementation barriers that can only be scaled at substantial additional costs. The extent to which these barriers can be removed effectively is of crucial importance to determine the real emission reduction potential and associated costs of identified options. Several types of barriers can be distinguished:

- Financial barriers;
- Policy and regulatory barriers;
- Institutional barriers;
- Technical barriers;
- Lack of awareness.

The starting point for barrier analysis is an identification of existing barriers. This requires a detailed assessment of the reasons why potential attractive options are not implemented. Once the reasons are known, the challenge is to formulate policy measures that remove these barriers and create an enabling market environment for investments in emission reduction options.

Strategy formulation

Once all options have been ranked according to their cost effectiveness, a strategy can be formulated to achieve the agreed emission reduction target. Strategy formulation involves the design of a package of options that meets the required emission reduction. In addition to the cost effectiveness, several other aspects that are not captured by cost effectiveness (such as implementation barriers, required investments, social impact, additional tax burden) are taken into account in designing the most appropriate package. By assigning relative weights to the various aspects, options can be compared with each other.

1.5 Adaptation assessments

Jan Verhagen[5], Michiel van Drunen[6], Frits Mohren[7], Marcel Rozemeijer[8] and Arjan van der Weck[9]

1.5.1 Policy background

Article 4.4 of the United Nations Framework Convention on Climate Change states that 'The developed country Parties and other developed Parties included in Annex II shall also assist the developing country Parties that are particularly vulnerable to the adverse effects of climate change in meeting costs of adaptation to those adverse effects'. Article 4.8 adds the following: 'In the implementation of the commitments in this Article, the Parties shall give full consideration to what actions are necessary under the Convention, including actions related to funding, insurance and the transfer of technology, to meet the specific needs and concerns of developing country Parties arising from the adverse effects of climate change and/or the impact of the implementation of response measures, especially on:

1. Small island countries;
2. Countries with low-lying coastal areas;
3. Countries with arid and semi-arid areas, forested areas and areas liable to forest decay;
4. Countries with areas prone to natural disasters;
5. Countries with areas liable to drought and desertification;
6. Countries with areas of high urban atmospheric pollution;
7. Countries with areas with fragile ecosystems, including mountainous ecosystems;
8. Countries whose economies are highly dependent on income generated from the production, processing and export, and/or on consumption of fossil fuels and associated energy-intensive products; and
9. Land-locked and transit countries.

Further, the Conference of the Parties may take actions, as appropriate, with respect to this paragraph' (United Nations, 1992). All countries in the NCSSAP comply with at least four of the criteria mentioned in Article 4.8.

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1.5.2 The IPCC Common Methodology

The IPCC Common Methodology (the Seven Steps Method - IPCC, 1991, 1992; Carter *et al.,* 1994) offers a general approach to assess the impact of sea level rise (SLR). It can be applied to different countries (especially developing countries) or different areas in a country to compare different vulnerability profiles or to compose overall vulnerability profiles. It can also be used to assess the vulnerability and adaptation in different levels of detail depending on amongst others data availability and for quantitative and qualitative assessments. Moreover, the method can be tailor-made to the specific circumstances and needs of a country. The Seven Steps Method includes the following steps:

1. The delineation of the case study area in the country at study and the specification of the sea level rise (SLR) and the climate change boundary conditions.;
2. The inventory of the study area characteristics yielding both the natural system data and the socio-economic data;
3. The definition of the relevant development factors and the economic scenarios of development;
4. The assessment of physical changes, socio-economic impact and natural system responses;
5. The formulation of response strategies and action plans;
6. The implementation feasibility of the action plans. Here several structural and carrying aspects of the society of a country are evaluated to determine whether the action plans can be implemented or that the implementation will encounter difficulties;
7. The identification of the types of assistance needed based on the potential problems encountered in the implementation of the action plans.

1.5.3 The UNEP/IVM handbook

The UNEP/IVM Handbook ‘Handbook on Methods for Climate Change Impact Assessment and Adaptation Strategies’ (Feenstra et al., 1998) was the first comprehensive guide for adaptation assessments in multiple sectors. It sets out a methodology based on climate scenarios and socio-economic scenarios (Figure 1.3). It includes separate chapters on water resources, coastal zones, agriculture, rangeland and livestock, human health, energy, forest, biodiversity and fisheries. The coastal zone section is ‘based on a combination of widespread experience using the Common Methodology and other methods for coastal vulnerability assessment, which have been developed in response or addition to the Common Methodology’ (Section 1.5.2).

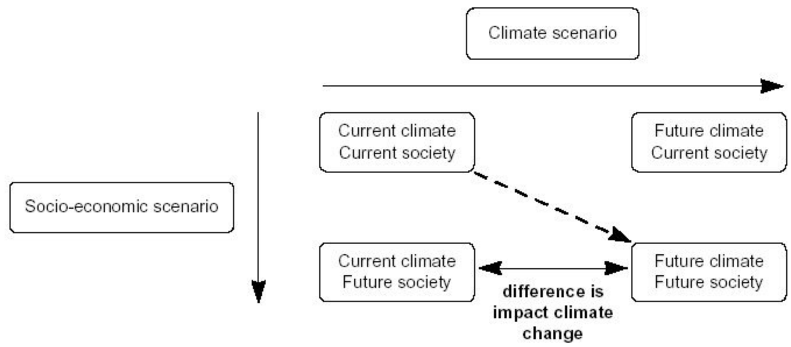

Figure 1.3 Climate and socio-economic scenarios (Feenstra et al., 1998).

1.5.4 Adaptation assessment approaches in NCCSAP

The adaptation assessments of the coastal zone studies in the pre-NCCSAP and the NCCSAP studies closely followed the IPCC Common Methodology (Section 1.5.2). In Chapter 2, six coastal zone studies are described: in Colombia (Section 2.3), in Ecuador (Section 2.4), Egypt (Section 2.5), Senegal (Section 2.10), Suriname (Section 2.11) and in Vietnam (Section 2.12). Section 0 provides a synthesis of the coastal zone studies. In the following subsections the approach of the water resources, agriculture and forestry projects will be presented.

Water resources

In the water resources sector, technology, economics, and institutions interact to make water supply meet water demand. In managing water resource systems, water managers ask, ‘Can we modify the management of current systems to adapt to climate change?’ and ‘How might climate change impact the design of new water resource infrastructure?’. The water resources sector by its nature is very adaptive, on various time and spatial scales. Also, water managers have a wealth of knowledge and experience managing under changing hydrologic and socio-economic conditions. This experience places them in a good situation to be able to adapt the operation of their systems to a change in climate, if that change is not too great or too rapid (Feenstra *et al.*, 1998).

Biophysical impacts

The main components of the hydrologic cycle are precipitation, evaporation, and transpiration. Changes in the climate parameters such as solar radiation, wind, temperature, humidity, and cloudiness will affect evaporation and transpiration. Changes in evapotranspiration and precipitation will affect the amount and the distribution, spatially and temporally, of surface runoff.

Climate change can affect the water quality in three ways. First, reduced hydrologic resources may leave less dilution flow in the stream, leading to degraded water quality or increased investments in wastewater treatment. Second, higher temperatures reduce the dissolved oxygen content in water bodies. Third, in response to climate change, water uses, especially those for agriculture, may increase the concentration of pollution being released to the streams. Together, these pose a threat to the water quality and the integrity of the aquatic ecosystem.

Socio-economic impacts

Water use is generally divided into non-market and market uses. Nonmarket water uses are aesthetic uses, certain recreational uses, and aquatic ecosystem integrity. Market water uses can be aggregated into five major water use sectors:

1. Agriculture: Irrigation and livestock;
2. Industry: Industrial, mining, navigation, recreation;
3. Energy: Thermoelectric cooling and hydroelectric power;
4. Municipal: Public supply, domestic, and commercial;
5. Reservoir.

An additional market use is dilution water for pollution abatement. It is typically considered a market use because it can be valued at the cost savings of additional waste treatment to meet water quality standards.

The water management system (i.e., water supply system) is made of two parts: surface water and groundwater. Although they are linked at the river basin water balance level, they are distinct in the water supply infrastructure. Climate change can affect the surface water supply via reduced flows into the storage reservoir or increased variability in inflow, which will affect firm yields from existing storage facilities. An additional impact in arid and semi-arid regions could be increased reservoir evaporative losses. The groundwater supply will be affected by increased or decreased percolation of water due to changes in the amount and distribution of precipitation and streamflow. This can lead to increased pumping costs if percolation decreases because of decreased precipitation or losses of soil moisture from increased

With great uncertainties about the local and regional impacts of climate change on hydrologic resources and uncertain future water demands driven by socio-economic change, an assessment of climate change impacts on water resources is a complex process. In addressing the sensitivity of water resources to changes in climate, the biophysical and socio-economic conditions must be considered (Feenstra *et al.*, 1998).

The goal and scope definition includes the following steps:

- Select the exposure unit (often a river basin) and the study area;
- Select a time horizon;
- Identify a preliminary range of adaptations;
- Determine general data availability;
- Determine the need for integration across sectors.

Models are often used to assess the biophysical components of a water resources assessment: hydrologic resources, water quality, and aquatic ecosystem integrity; and the socio-economic components: demand from water use sectors and the water management system. Feenstra *et al.* (1998) provide an overview of such models.

Once an assessment method has been selected and tested and the necessary data have been collected, the key inputs and assumptions need to be formulated. Before applying a method it is necessary to develop climatic and socio-economic baseline scenarios, climate change scenarios, and assumptions about the potential for autonomous adaptation.

Possible adaptation options include:

- Modification of existing physical infrastructure;
- Construction of new infrastructure;
- Alternative management of the existing water supply systems;
- Conservation and improved efficiency;
- Technological change;
- Market- or price-driven transfers to other activities.

In Chapter 2, three water resources studies are described: in Ghana (Section 2.6), in Mali (Section 2.8) and in Mongolia (Section 2.9). Section 3.4 provides a synthesis of the water resources studies.

Agriculture

Agriculture, the art of cultivating the soil, growing and harvesting crop and raising livestock, combines agronomic and economic aspects of the utilisation of ecosystems by a household or farmer. Agriculture is, in many countries, the most important economic activity: both in terms of cash flow as well as in terms of labour.

For agriculture the management of soil, crop and livestock is modelled. The impact of changing climatic conditions can be calculated used the model, based on the results changes in soil, crop and livestock management can be implement. The adaptive capacity of a system will determine whether such adaptations are implemented. The emissions inventories (N_2O, CH_4 and CO_2) were not linked to the agricultural studies but were included in the mitigation studies.

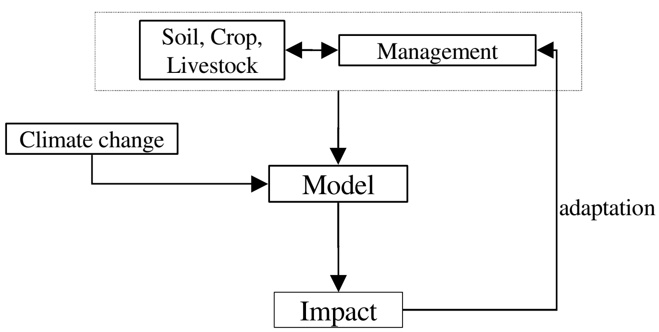

Figure 1.4 Impact and adaptation.

Agriculture was part of the following countries studies: Bolivia, Bhutan, Costa Rica, Mali, Mongolia, Senegal and Yemen. The task for the technical assistant was to provide tailor made assistance building on locally available knowledge, tools and data. The assistance focused on impact and vulnerability assessment and the definition of adaptation measures.

Impact assessment

A framework prepared by the UNEP/IVM Handbook (Feenstra *et al.*, 1998) was distributed among the participating groups. The NCCSAP stresses the importance of simulation models in determining the impact of climate change on primary agricultural production. The effects of changes in temperature, precipitation, and CO_2 on production levels can be calculated using such models. Based on the simulation results, impact on farm and village output and income are determined. These findings may be extrapolated to the regional and national level to assess the impact of climate change on food security. Figure 1.4 depicts the structure used in the impact studies.

From an agronomic perspective food security starts with crop production at the field level moving up to the farm, regional and national level. With the changing spatial scale, the focus of research changes from an agronomic or biophysical analysis to a socio-economic and political analysis (see Figure 1.5).

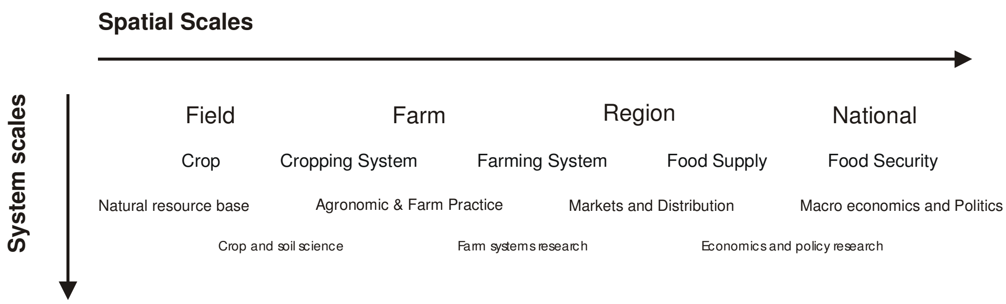

Figure 1.5 Spatial and system scales linking crop production to food security.

Most studies in the NCCSAP addressed issues of impact on production levels at the left hand side of Figure 1.5. Up-scaling of these findings to a regional and national scale was in most cases difficult as data and clearly defined socio-economic scenarios were lacking.

After having determined the impact of climate change on agricultural production, measures to adjust to the changed environmental conditions need to be defined. The effects of some technical adaptation measures such as changed planting date, moving to other varieties or crops, irrigation, weed control etc. can be quantified with relative ease. Again, higher level impacts, at the regional and national scales, such as changes in political and institutional settings were addressed in more general terms.

Adaptation

In general, two pathways are distinguished. The first is mainly an agronomic study focusing on crop production at the field and regional level. For this analysis the results of crop simulation models are used to reveal the difference between calculated crop production under current and changed climatic conditions. As most models only combine the effects of temperature, precipitation and nutrient input for a given crop-soil combination, differences in calculated yields can be explained based on these factors. Consequently adaptation measures based on crop simulations are also limited to these factors.

Other factors such as pest, diseases and weeds are dealt with in a semi-quantitative manner or more descriptive manner.

The second pathway combines the agronomic analysis with socio-economic, technical, institutional and political aspects influencing production levels or food security. This approach offers a linking to current agricultural programs. The impact of climate change on the socio-economic position of different types of farmers and options for adaptation are also evaluated.

Depending on availability of data, technology and expertise, the regional distribution of impacts and adaptation measures are part of the analysis. The context of global change expands the studies trying to incorporate changes in consumption pattern, demographic development and technological progress to address future demands for food, fibre, water, and space. The NCCSAP also tried to look at cross-sectoral effects, competition for scarce resources, such as water.

In Chapter 2, two agriculture studies are described: in Bolivia (Section 2.2) and in Yemen (Section 2.13). Subsection 3.6.1 provides a synthesis of the agricultural studies.

Forestry

Both agriculture and forestry contribute to economic development in terms of income generation and employment. In most developing countries industrial transitions will be linked to changes in agriculture and forestry. Besides changes in the production systems, these transitions will also involve changes in the industries and services based on these production systems.

Agriculture and forestry aim at producing food and fibre. To achieve this sustainable management and use of natural resources is crucial. Quite often however, because of lack of proper knowledge or because of overexploitation, this is not warranted. The way in which land is managed determines to a large extent the quality of natural resources such as water, soil and biodiversity. Poor management is also reflected in the quality of landscapes as it can be seen in abandoned irrigated and eroded landscapes. It will be a main priority to find a safe and responsible way to feed the growing population, which also will require the inclusion of environmental management in order to reduce long- and short-term vulnerability and to protect the natural resource base from overexploitation.

Climate change is an additional stress to systems that are, often, already under stress from other pressures. Since changes and variations in climate and other environmental factors have occurred naturally, ‘adaptation’ is not a new phenomenon. Both human and natural systems have repeatedly adapted to changing conditions.

Agriculture has traditionally been the key livelihood strategy for most people living in rural areas based on the main function of agriculture to provide food. Forests will not only be affected by climate change but will also provide option to generate capital via the Clean Development Mechanism (Section 1.4.1).

Climate is not a peripheral question for development. Today already, the natural variability of rainfall, temperature and other conditions are among the main factors behind variability in agricultural production, which in turn is one of the factors behind food security. The challenge facing agriculture is to produce enough food and at the same time, ensure that the natural resource base remains productive for the future. The main question is what the role of agriculture is in the development of the countries concerned.

Subsection 3.6.2 provides a synthesis of the forestry studies.

2. Country experiences and highlights

2.1 Introduction

In this chapter the key NCCSAP project members of most countries involved in NCCSAP or the pre-NCCSAP studies summarised the results of the study the selected themselves. Only the contributions of Bhutan and Costa Rica are lacking, because in these countries the studies were not finished and the project team separated, respectively. As can be seen from Table 2.1, twelve vulnerability studies were chosen and one mitigation study. Six of the vulnerability studies concerned coastal zones, three water resources, two agriculture, and one the effects of extreme weather events.

Table 2.1 Overview of studies summarised in this chapter.

Country	NCCSAP / Pre NCCSAP	Subject	Section
Bolivia	NCCSAP	Vulnerability / agriculture	2.2
Colombia	NCCSAP	Vulnerability / coastal zone	2.3
Ecuador	NCCSAP	Vulnerability / coastal zone	2.4
Egypt	Pre NCCSAP	Vulnerability / coastal zone	2.5
Ghana	NCCSAP	Vulnerability / water resources	2.6
Kazakhstan	NCCSAP	Vulnerability / extreme events	2.7
Mali	NCCSAP	Vulnerability / water resources	2.8
Mongolia	NCCSAP	Vulnerability / water resources	2.9
Senegal	NCCSAP	Vulnerability / coastal zone	2.10
Suriname	NCCSAP	Vulnerability / coastal zone	2.11
Vietnam	Pre NCCSAP	Vulnerability / coastal zone	2.12
Yemen	NCCSAP	Vulnerability / agriculture	2.13
Zimbabwe	NCCSAP	Mitigation / energy sector	2.14

Besides the study summaries, the authors included a reflection on the experiences and lessons learned. Here they describe the applicability of the methodologies used, experience with multi-disciplinary research and policy implications.

The sections end with a list of follow-up studies and conclusions.

2.2 Bolivia

Oscar Paz[10], Javier Gonzales[11] and Magali García[12]

2.2.1 Introduction

The Government of Bolivia, aware of the importance of sustainable development reoriented its national policies and included the concept of sustainability in all its actions since 1993. Until then the extractive policies in the country lead to a deterioration of the environment. One of the observed critical aspects was the occurrence of extreme events (floods, frosts, droughts) that made the community to presume the imminence of a future climate change. This could severely affect the productive capacity of the country and could affect its food security.

Bolivia ratified the United Nations Climate Change Convention (UNFCCC) in July 1994 and created in the same year the National Program of Climate Change (PNCC in Spanish), within the Vice-Ministry of Natural Resources and Environment of the Ministry of Sustainable Development. PNCC's intention is to fulfil Bolivia's obligations under the Convention. In 1999, the government ratified the Kyoto Protocol and is currently implementing Kyoto goals throughout the Clean Development Mechanism.

Following the above-mentioned policies, in 1998 the Government of Bolivia signed a co-operation agreement with the Government of the Netherlands through the Netherlands Climate Change Studies Assistance Programme (NCCSAP). One of the main reasons for this co-operation was that Bolivia had to increase its capacity to be able to implement UNFCCC tasks and goals, and to gather more knowledge on the effects that climate change could have on its production and its environment.

Furthermore, the undertaking of these activities would allow generating a frame to strengthen capacity in the involved institutions. In the future these could help to improve the understanding of causes and implications of climate change. The agreement implied sound support to Bolivia for developing the fundamental elements for its First National Communication such as the Inventories of Greenhouse Gasses (GHG) with a baseline of year 1994, studies on mitigation of greenhouse gas emission, studies of climatic scenarios and vulnerability and adaptation analysis of the agricultural, livestock, forest and water resources sectors. This work was developed in coordination with the State University of San Andres[13], the National Service of Meteorology and Hydrology (SENAMHI) and two NGOs[14]. Its results constituted important inputs for the development of the First

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[14] Initiative for the Defence of the Environment (LIDEMA in Spanish); Bolivian Academy of Sciences.

Communication of Bolivia for the UNFCCC, which was presented at the Sixth Conference of Parties (COP6) in The Hague.

The results obtained in the different studies, showed that the agricultural sector would be affected by climate change, partly because it is the economic sector that makes the least use of technology in the country and also because it constitutes the sector with the greatest direct dependence on climate for its productivity. In addition climate variability affects the food and productive security of a great part of the country's population. Therefore in this section the results of vulnerability and adaptation studies for the agricultural sector shall be presented.

2.2.2 Approach

The study was based on the use of the crop simulation model DSSAT3, which included the possibility of modelling the effects of an increase in the atmospheric CO_2 concentration and variations of temperature and rainfall on production in representative Bolivian agricultural areas. The model was run using data from previous climate change simulation studies. A sensitivity analysis of agricultural ecosystems to climate change was performed. Previously to the simulation runs, a validation was performed with available field data. For the study itself, potato (*Solanum tuberosum*), maize (*Zea mays*), soybean (*Glicine max*) and rice (*Oriza sativa*) were selected because of their economic importance and/or because of the role for food security in Bolivia. The modelling included the simulation of crop production under incremental climatic scenarios assuming maximum variations of ±4°C of temperature and ±30% in rainfall. The effects of CO_2 increase were also simulated assuming a doubling of the present concentration (660 ppm). The adaptation studies were analysed through the application of a matrix for qualitative evaluation of the effects of climate change.

2.2.3 Results

Before coming to the description of the results obtained in this study it is important to mention that Bolivia includes 3 different and preponderant agricultural regions: a) The Altiplano region, located over 3600 metres above sea level (masl), is characterised by the production of Andean crops (potato and quinoa), extremely rustic and resistant to the harsh climate conditions of the zone (droughts and frosts during the cropping period); b) the valley region situated around 2600 masl, producing mainly potatoes, white maize and legumes; (production in these two zones is mainly for local food consumption) and finally c) the zone of the low plains (200 masl) where extensive agriculture areas are cultivated mainly for export.

Regarding the climatic characteristics and according to the studied scenarios, in the Altiplano areas as well as in the lowlands (which constitute the departments with the largest exporting agricultural activity), few variations in the total precipitation is anticipated. The number of days with precipitation shows a tendency to decrease (Garcia, 2003). There is an increased occurrence of storms and also the mean minimum temperature shows a clear increase. In the Andean Valleys the tendency is a shortening and intensification of the rainy period, apparently due to the combination of global climate change and local desertification. An increase of temperatures is also expected, which is likely to affect the vegetative cycle of the crops.

The modelling of the four crops mentioned in Section 2.2.1 was performed as follows: *potato* was analysed in the Altiplano and Valleys, *white maize* in the Valleys, and finally *soybean* and *rice* in the lowlands of the country (Figure 2.1). In general the results show that a temperature increase of 2°C, would not lead to serious damage to crops, unless this rise is accompanied with an increase in rainfall. Moreover, in the case of the Altiplano, where the low temperatures slow down crop growth and extend their vegetative cycles, the increase in temperature would accelerate crop growth and would finish the productive period before the start of the frost period. If a modest increase in temperature takes place without increase in precipitation adaptive measures are needed, such as the incorporation of irrigation systems and improvement of the crop activities to maintain production. If a *reduction in precipitation* takes place all the studied ecosystems would be affected negatively.

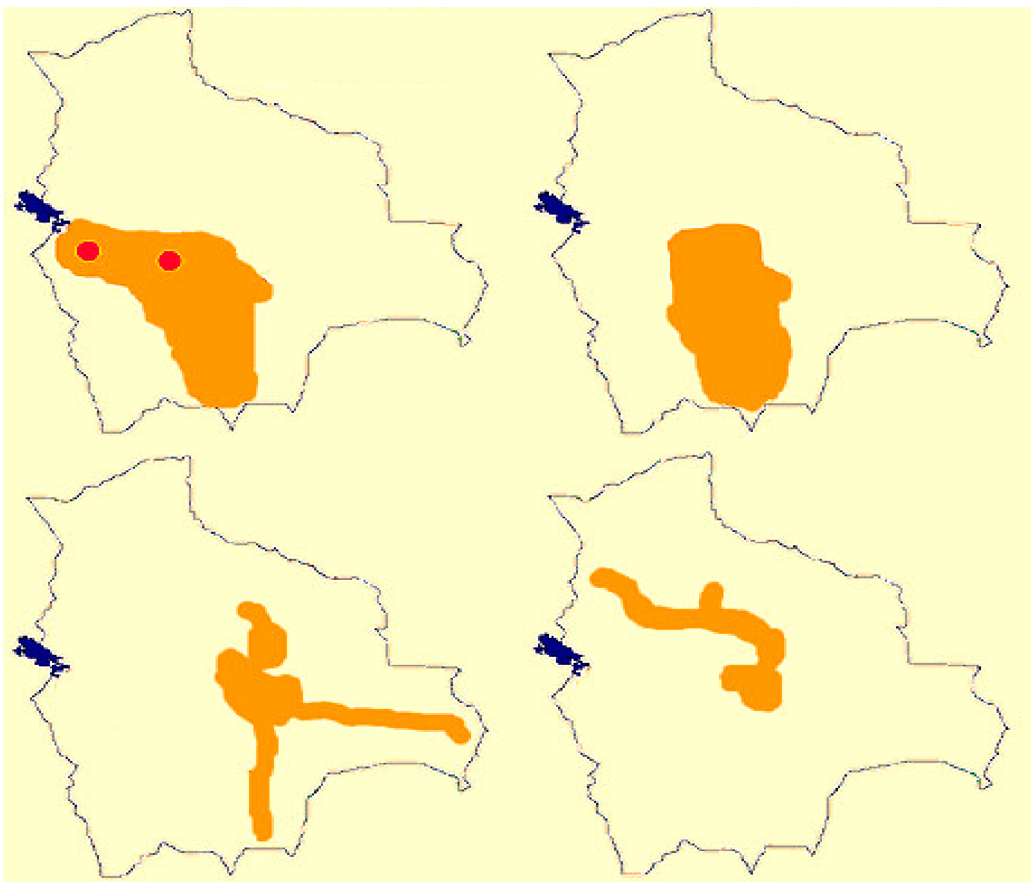

Figure 2.1 Production areas (clockwise) of potato, maize, rice and soybean. The two round spots in the potato map indicate the case study areas. Source: PNCC.

In the case of *potato*, the studies indicated (Figure 2.1) that in the Altiplano the increase of temperature would be positive for the crop because it would accelerate its physiological activity if early frosts will become less common in the zone. If the temperature increase is accompanied with an increase in rainfall, yields would be affected even more positively by 20% on average. Due to the high altitude of the Altiplano, the CO_2 concentration is currently low, (Vacher, 1998) limiting photosynthesis. Therefore an increase in the CO_2 concentration together with an increase in temperature and precipitation, would favour the productivity. In the Valleys, similar effects as in the Altiplano could be perceived for potato but with more modest increases until 10%. However, in all cases, rainfall reduction would have serious negative impacts on crop production, as can be seen from Figure 2.2.

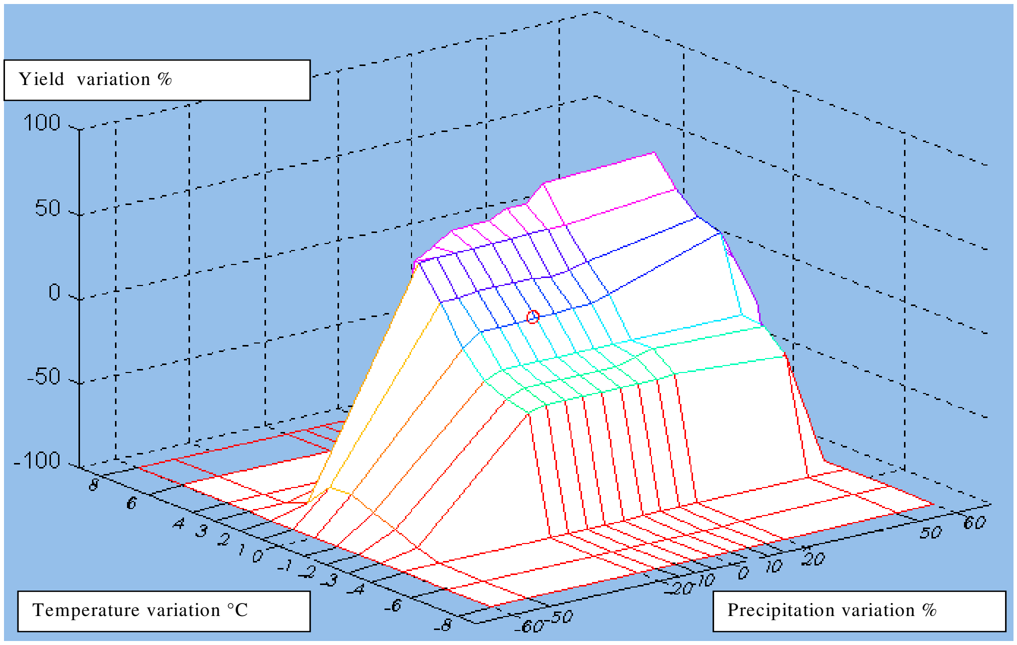

*Figure 2.2 Yield variation of potato (*Solanum tuberosum*) (%) as determined by the temperature and rainfall variation in the Altiplano. Source: Institute for Agricultural Research (UMSA).*

In the zone of the valleys, irrigated *white maize* turns out to have a high physiological sensitivity to climate change. Yields showed a clear reduction under all scenarios predicting a temperature increase (under any precipitation regime) with an average yield reduction of 25%. A yield reduction was registered in spite of the increase in the CO_2 concentration that theoretically should decrease the need for to water. Apparently the sensitivity occurs due to the crop tendency to abort flowers under high maximum temperatures, which cannot be compensated by irrigation or by the increase of CO_2. The analysis of the *rainfed maize*, showed different results as yields increased up to 50% for all climatic scenarios (temperature increase, and/or modest variations of precipitation) and doubling of the CO_2 concentration. The reason is that rain fed maize at present produces very low yields due to the intense water stress the crop undergoes. This water stress is more important than the negative effects of the high maximum temperatures. Under these conditions the doubling of CO_2 would help to reduce the water stress. This gain could be maximised with the application of adaptation options such as the installation of irrigation systems and improved crop management.

Soybean modelled in the lowlands of the country, showed high physiological sensitivity to climate change. For the winter season (dry season) with rainfall reduction and temperature increases, the vulnerability analysis showed yield reductions of up to 45%. This is mainly caused by the severe water deficit and the shortening of the phenological phases of flowering and grain filling. In case of an increase in precipitation, yields could be increased up to 43%, if the temperature increase is modest. When temperature increases are high, reductions in the yields will take place again. These effects cannot be mitigated by the increase of CO_2 concentration under these scenarios. In the summer season (rainy season) yields are negatively influenced by the temperature increase with or without increase in rainfall variation (Figure 2.3). The maximum temperatures are much higher than in winter, which affects the flowering and grain filling phase. Changes in precipitation will not affect the production severely, as long as it does not exceed ±20% variation from the range it moves currently.

The increase of CO_2 would have positive effects on the soybean production under all scenarios, with yield increases of up to 50% attributable to the best physiological use of CO_2.

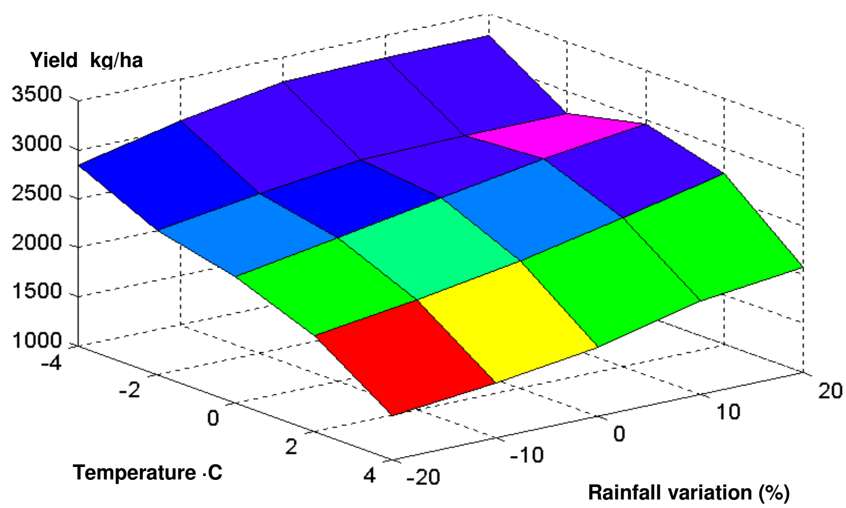

Figure 2.3 Soybean yields under various variations of Temperature and Precipitation during the summer season (rainy season) (2xCO_2). Source: Institute for Agricultural Research (UMSA).

Under similar climatic conditions as the soybean (lowlands), vulnerability studies showed that rice will be little influenced by climate change, because the present conditions are optimal for the crop and smooth variations both in precipitation and in temperature will not affect yields. The incrementing climate scenarios showed that at extreme reduction in precipitation, (up to 20%) added to an extreme increase of temperature of 3°C, the yield will be reduced with 15%. The drop is not that large because the currently rainfall rates are very high. The influence of the doubling of CO_2 has little effects on yield (increase of 5%) if the precipitation levels are similar to the present ones, even under of strong elevations of temperature.

The results presented above are similar to the observations made in other areas of the world: crop yields in tropical and subtropical zones will be reduced due to the combination of both temperature and water stresses. The results of these studies are compiled in the second and third assessment report of the IPCC (IPCC, 2001). Because the climate change scenarios performed in earlier studies for Bolivia, indicate an average expectation of a temperature rise of 4°C and an average variation of ±15% in the mean precipitation, one may expect a reduction of yields in case no adaptation measures are to be implemented in the highlands and in the valleys, but little variation in the lowlands.

2.2.4 Experiences and lessons learned

Although the models were calibrated before running the simulations, their application faced some problems. The most important one was the lack of input information. In developing countries such as Bolivia where research is not of national priority, extremely detailed basic information as that required for the models (for example CERES) is very difficult to find. Even in the case it exists, this information is of low quality and difficult to access. For the present study, many of the default parameters for the models had to be used, since reliable information from the field was missing. Examples include photosynthetic efficiency and growth equations. In this regard, the team worked very closely with researchers from the Faculty of Agronomy of the State University of La Paz, who granted the criteria to provide reasonable assumptions. In spite of the limitations, with few data and a reliable validation, the models produced outputs well correlated with the agricultural situation prevailing in the country. Since the baseline scenarios were well described it was reasonable to assume that the simulated scenarios would reflect the future situation in the country.

Due to the lack of adequate information to consider a more extensive study, the results have a limited value. Nevertheless, they explored the different critical aspects of the vulnerability of agriculture to define as clearly as possible the effects of Climate Change. When evaluating the model results it is important to consider the different sources that may cause variation. One of these sources could be the existing large biodiversity in the country, which could influence the foreseen results especially in regions where mono cropping is not a general practice. This is case in areas where white maize and potato are cultivated.

The sensitivity analysis of the studied crops (potato, maize, rice and soybean) suggested possible phenological changes caused by the increase in temperature and atmospheric CO_2. This is not certain because the impacts might be compensated with physiological adaptation of the crops. A clear overview of the impacts of climate change on agriculture cannot be obtained yet, only the tendencies can currently be described.

For Bolivia the climate variability in the country is not fully understood yet. The level of knowledge of the climatic variability in the country is not consolidated yet in a solid baseline for the use of these scenarios. There are only a few climate studies that describe the climatic patterns of the country. The combined effects of the latitude (tropical latitude) and physiography of the country (diverse altitude) make it difficult to make good projections for the country. In many cases the results can only be considered hypothetically.

One of the most evident learned lessons is that there is a need for better understanding of the climate variability in the different regions of the country. This is needed to perform a correct interpretation of the results obtained in all sectors. Insight in the trend of climate change can contribute to an additional understanding of the climatic baseline and future scenarios and could amplify the use of sensitivity models.

Another aspect that has not been considered in the studies, but which is absolutely relevant for understanding the impact of climate change in mountain ecosystems is the withdrawal of glaciers in tropical mountains. This could have strong consequences on local and regional hydrology and indirectly on agriculture. It should be considered as a political priority to research the impacts of the expected changes.

The simulation models used in the studies require a large amount of climatic and physiological information and this information was not always available. This caused that in many cases the work was done with default values, which seriously affects the validity of the obtained results. The use of simpler models could make the vulnerability analyses easier, without sacrificing the precision of the results. In this way a suitable balance can be found between the efficiency of the proposed models and their data requirement. On the other hand these models consider only the behaviour of the species and sectors independently of the inter-specific and inter-sector interactions, which are common in most of the Bolivian production systems. For that reason a multidisciplinary approach must be considered in future evaluations, because the interactions within productive systems might greatly influence the impacts of climate change.

The studies also favoured the increase of knowledge of the subject of climate change and of the application of simulation models, in all sectors. A positive effect is that students and lecturers of the State University learned to work with these models, which has a strong multiplying effect for the new generations of professionals. Finally, it is important to mention that the studies formed and strengthened the base of the design of policies that used to be absent in Bolivia. The studies helped in the processes of understanding the impacts of climate and global change and supported the formulation of national strategies to deal with these impacts. The PNCC takes the lead in this as can be seen from Box 2.1.

2.2.5 Follow-up research

The influence of the results of the study on the collective conscience of climate change was reflected mainly in municipalities and universities. The study results served as guidelines for field studies carried out afterwards. In many cases, the field studies confirmed the obtained results.

In order to have a better overview of the local and/or sector vulnerability, the studies must review different measurable elements of the climate such as changes in the regional hydrology and crop sensitivity. At the same time they should also evaluate the local economic, technological and institutional capacities of the population. It is evident that from the perspective of local response capacities, the results based on the use of simulation models must be complemented with studies and methodologies on the different institutional adjustments to face the impacts of the climate change (what the IPCC has denominated spontaneous adaptation). In this sense there have been proposals to continue with the studies made in this first stage, with the inclusion of the evaluation of local capacities and the extension of the geographic scenarios to validate and to complement the obtained data. Unfortunately the lack of national and international support has limited these efforts.

Box 2.1 The impulse of the National Program of Climate Change.

The National Program of Climate Change (PNCC) has promoted a gradual mentality shift in the Bolivian Society about the importance of considering a detailed analysis of the Climate Change.

The PNCC, has developed a number of activities for and together with the National University. The PNCC intensified its efforts to work with the University because it considers the training of trainers as one of the best forms to multiply the awareness about the climate change issues. In this regard, the PNCC in the frame of the project, organised several training courses and exchange seminars with the University in its different Institutes. In this way the personnel of the State University received an intense qualification in the subject of climate change, in such a way that to the present the number of academic research related to the Global Change has increased notoriously.

The establishment of the Inter-institutional Council of Climate Change (ICCC) was initiated by the PNCC and at present ICCC plays an important role in advising on climate change policies in the country.

Finally the development of the national strategy for the implementation (ENI) of the United Nations Framework Convention on Climate Change (UNFCCC) is a result of the NCCSAP project.

The studies also suggested exploring the technical aspects of adaptation mechanisms in more detail. Since the moment the NCCSAP studies were finished, a series of subsequent studies were performed evaluating the impact of agronomic adaptation measures, to explore better-adapted species to situations of extreme events and to determine the incidence of reductive factors to the productivity. Unfortunately, these studies were superficial, due to the lack of financial support. It is important that governments and international institutions prioritise those adaptation studies that will also effectively investigate future extreme meteorological events.

One of the remaining activities is to improve the understanding of climate variability in the different regions of Bolivia. A greater insight could improve the use of the incremental scenarios in these regions. Since the ending of the NCCSAP program, advances have been made in reviewing the trends in local precipitation regimes and in some natural distortions as those provoked by *El Niño*. One of the greater deficiencies in Bolivia is the lack of real time information to be able to confront emergency situations. Given that the latter is a basic need to get precise results. The real time information network needs to be supported by local governments as well as by the international institutions, to the present this has not been constant and durable.

2.2.6 Policy implications

Although the analyses of vulnerability and adaptation, carried out with the support of the NCCSAP program, left many open questions and included various assumptions, these are the only studies on the effects of climate change in Bolivia. Therefore they have been already included in the context of the public policies. For example the sensitivity studies suggested to develop adaptation measures related to water management and to exploit the capacity of crops for extreme situations (date of sowing, selection of varieties, etc). Some of these actions are already being implemented by national programs as in the case of irrigation or the production of better-adapted crop varieties. Nevertheless in many institutions the conscience of the importance of climate change does not exist yet, and their activities do not include considerations to reduce the vulnerability to climate change.

It is important to mention that the obtained results have served as base for the elaboration of the National Strategy for the Implementation (ENI in Spanish) of the UNFCCC that recognises the adaptation to climate change as the central axis of the national policy. The ENI has been elaborated with the component members of the Inter-institutional Council of Climate Change (ICCC) that was structured as a direct consequence of the analysis of the results obtained in the studies. Although the ENI shows the way that should be followed for the implementation of policies, many involved actors do not recognise the importance of the climate change yet. Therefore it is still necessary to increase the number of qualified people and raise awareness on the subject.

On the other hand, besides the importance of the results obtained and their inclusion within the national policies, the implementation on lower governmental levels is also important. Many environmental management decisions are a municipal task, which is a result of the Law of People Participation. The central government does not include these actions within its obligations any longer. Under this characteristic, it is very difficult to include scientific results in Municipal policies when the actors were not included in the definition of the research priorities and in the validation of the results. In many cases the Municipalities do not even hire technicians related to environment and/or ecology and the inclusion of the climate change topics as high-priority is difficult and hardly feasible. For that reason it is suggested that the coming research should include local stakeholders to define the actions for the implementation of adaptation and mitigation of the effects of climate change. Hence a less complex and more participatory approach is required.

2.2.7 Conclusions

In general the results of the studies indicated an increase of temperature up to 2° C. This would not lead to unless if this rise will be accompanied by an increase in rainfall. In the Altiplano the increase in temperature would accelerate crop growth and the productive period would be finished before the start of the frost period. If a modest increase in temperature takes place without increase in precipitation, adaptive measures are needed, such as the incorporation of irrigation systems and improvement of the crop activities to maintain production. If a *reduction in precipitation* takes place all the studied ecosystems would be affected negatively.

An important degree of awareness on the theme of climate change at the research institutes was crated. These institutions were strongly involved in the process of analysis and knowledge of methodologies and techniques for the different components of the project. The IPCC´s guidelines and methodologies for the national inventories of greenhouse gasses have been spread. The understanding of simulation models allowed analysing the possible impacts of climate change in important sectors as agriculture, forestry and water resources. This meant an important qualitative advance in understanding the levels of vulnerability of the different ecosystems and the strengthening of the national capacities for climate research.

The qualification of personnel for the management of the General Circulation Models, was relatively important, because this activity showed the enormous difficulty for their application over large areas of land, as that of Bolivia and with such a large climatic diversity. The need to count on models of a greater space resolution is obvious to improve the understanding of the possible climate changes at mesoscale level. The studies also revealed the great lack of institutional capacity for climatic research by the national agency in charge of this and the urgency of qualification of its personnel, as well as the necessity of better equipment.

The studies helped to identify the countries vulnerability to climate change impacts and to strengthen the central strategic line to develop adaptation measures for all sectors, especially for those related to food security, water resources and natural risks. A clearly detected limitation on which has to be worked on in the future is the identification of adaptation actions, in a joint action with the local communities, taking advantage of their experience.

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2.3 Colombia

Paula Cristina Sierra-Correa, Francisco Arias Isaza, David Alonso and Carlos Andrade[15]

2.3.1 Introduction

Located in the northwestern tip of South America, Colombia is a country with 1642 km of coastline in the Caribbean Sea continental margin and 2188 km towards the Pacific, with approximately 52 km of coastline in the insular regions.

The evidence of and great concern related to the impacts of Sea Level Rise (SLR) on low land coastal areas have prompted Colombia to start its own climate change vulnerability and adaptation assessment titled *'Defining vulnerability of bio-geophysical and social-economic systems due to sea level change in Colombia coastal zone (Pacific and Caribbean) and adaptation measures'*. The project used the Intergovernmental Panel for Global Change (IPCC) methodology to evaluate a general preliminary adaptation measures, based on available information, scientific and policy analysis and expert knowledge (see also Section 1.5.2).

The results show that especially the institutional, legal and organisational settings make Colombia highly vulnerable to SLR. Although more than enough legal documents related to coastal management exist, they remain isolated and sector oriented. Especially integration between execution, monitoring and enforcement levels of administration is lacking. In addition competency and interest conflicts exist between the administrative entities as well as with the economic development sectors that benefit from coastal zones. There are also technical deficiencies within institutions to engage in the subject, and at the moment, there are no technology, information, design and execution strategies at the scientific, technical, social or economic level.

Results from the analysis on response options and feasibility of implementation, measured by its legal, institutional, economic, financial, technical, cultural and social aspects, show that the national capacity to respond to SLR is limited. These results placed the country's vulnerability between high and critical; also, future perspectives urged to establish Integrated Coastal Zone Management (ICZM). The population in the Colombian coastal zone is expected to increase at a higher rate than the national average. In addition, serious plans for large-scale developments such as ports and industrial areas have been revealed to economically develop the coastal region at an increased rate.

To give perspective on the details of SLR impact, three pilot case areas were studied in the project. On the Pacific coast the Guapi-Iscuandé area and San Andrés de Tumaco were selected. Along the Caribbean the large estuarine area covers the Sinú River delta system and the Gulf of Morrosquillo. The Guapi-Iscuandé area represents a vulnerable area with a low economic capacity to finance any measures. The two later represent areas where large-scale economic development has been planned. The case of the Gulf of Morrosquillo will be presented in more detail in order to give an example of the results.

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2.3.2 Approach

The methodology used was the so-called IPCC Common Methodology (IPCC, 1992, 1994). This method consist of seven different and inter-related steps, resulting in an Action Plan providing means to mitigate the SLR impacts and identify response strategies to cope with SLR (Section 1.5.2). This method has the advantage of reducing costs and is useful as it enables the comparison of results between countries, facilitating the augmentation of information to achieve more knowledge of global vulnerability.

The project began by defining the study area, INVEMAR (2003a), followed by a characterisation and inventory of all aspects related to the problem (INVEMAR, 2003b). Later, scenarios were defined to quantitatively analyze the vulnerability assessments of the impacts in the natural and socio-economic systems (INVEMAR, 2003c). The next step was the evaluation of the impacts, effects and responses of the natural system on higher sea levels, coastal erosion, coastal inundation and saline intrusion and to the associated socio-economic impacts to those responses (INVEMAR, 2003d). With this knowledge the different response strategies that could be used in Colombia were analyzed, through a multi-criteria analysis for adaptation strategies (INVEMAR, 2003e). Afterwards, the quantitative analysis for vulnerability assessment was developed (INVEMAR, 2003f). Finally the project formulated an action plan with suggestions on how to imbed proactive changes into the existing institutional framework and prioritise actions to be developed at the different government levels to ensure preparedness for SLR (INVEMAR, 2003g).

The case study areas were selected to show the practical implications of SLR and to increase the public awareness about the effects of climate change. The characterisation of the coasts of Colombia, regarding life quality indexes, population concentration and migratory processes, were relevant factors taken into account during the selection process. The cultural diversity in the Caribbean and Pacific Region embraces different indigenous groups and Afro Colombian groups to whom different resources and exploitation methods are attributed e.g. there is a greater development in cattle raising, mining and industry in the Caribbean in comparison to the Pacific region. For this reason, one culturally representative area on each of the coasts was used. Below we will focus on the Morrosquillo Gulf area. It contains an important urban area and shows the possible direct impact of SLR on human settlements.

2.3.3 Results of the Gulf of Morrosquillo study

To define the study area, physical, biological, social, economic and political criteria were taken into account. There are sharp differences between the Colombian Caribbean and Pacific coasts. Because of this, the physical criterion of land altitude was chosen to chief the study area definition, since it is particularly dominant in the coasts dynamic processes. Unfortunately, existent cartography lacks sufficient detail and the study area had to be delineated by the available +60m and -200m contour lines. A 1:300.000 scale was defined for the project.

The study area was tested for the following components: bio-geophysical, social-economic and governance which are needed to evaluate the vulnerability assessment (VA) due to SLR. Related effects such as erosion, salinity intrusion and inundation were also considered. Very strong assumptions would have to be made in order to extrapolate the available information to a different scale. Indicators such as demography, quality of life, and economic development as well as national, regional and local governance were also evaluated in the case study areas.

The Sinu river estuary and Morrosquillo Gulf environmental coastal unit is shaped by a mosaic of continental, coastal, insular and marine ecosystems that spreads on the central Colombian Caribbean coast for approximately 260 km. This zone includes the coasts of Tortuguilla Island, Fuerte Island and the San Bernardo Islands Archipelago. Morrosquillo's Gulf has an approximate area of 1000 km^2 and depths between 15 and 55 m. An extensive coastal plain limits it on the north and south with two coral terraces. The evolution and dynamics of the southwest sector, located around the Sinú River mouth, depend on the fluvial and marine processes, and is especially affected by the rate of waves and tides. The case study area covers the south part of Morrosquillo's Gulf from the Tolú's municipal head-board to the Rada Point, see Figure 2.4.

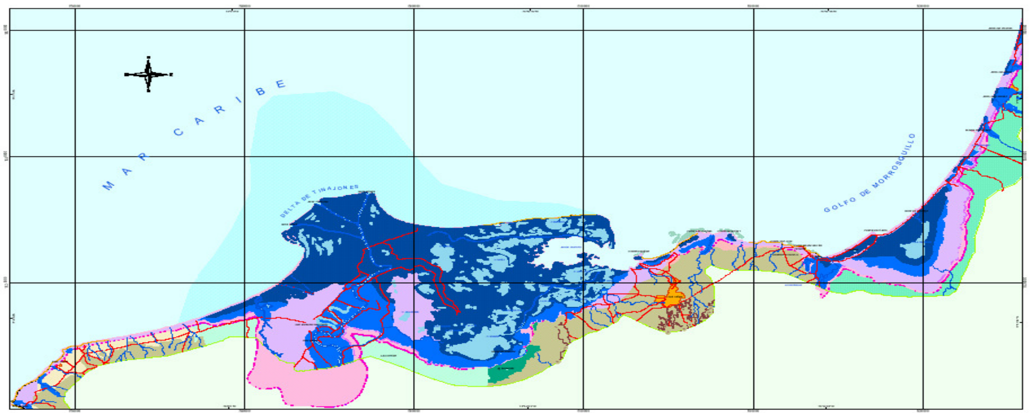

Figure 2.4 The Gulf of Morrosquillo area.

An important characteristic of this area in relation to the VA is the presence of the Sinú River delta. The basin of the Sinú River is the most important of the region with an area of 13.700 km^2. The basin influences the water salinity in the Gulf, specifically in the south sector. During the rainy season, the salinity distribution shows values between 26.5 and 31.8 ppt due the river discharges.

From a geomorphological point of view, the study area is divided into five regions, within which different geomorphologic units can be identified according to their origin and/or evolution: alluvial, marine, denude, structural and lacustrine. These units are in constant change and are influenced by marine processes such as waves, tides, coastal currents and terrestrial processes including the exhaust of rivers, the river influence, or processes of action in mass. Human influence has demonstrated to be decisive in altering the units, primarily through structures that try to protect the beaches against the coastal erosion.

The marine and coastal environments encountered in the southern area of Morrosquillo's Gulf, are mangrove ecosystems, coral reefs, meadows of sea grass and soft bottoms communities typical of the continental shelf, estuaries, deltas and coastal lagoons. These environments are part of the whole geomorphologic environment of the coastal zone, serving as a habitat for different biological resources and used as a means of sustenance by a great part of the population of the coastal zone of the area. The mosaic of ecosystems found in this area and the dependence of local population permitted the assessment of the vulnerability of these systems to sea level rise with the purpose of extrapolating the impacts and changes to similar environments of the entire Caribbean coastal zone.

The Morrosquillo's Gulf is not only important for its physical characteristics and biological diversity, but also for its social economic aspects and development problems. The inhabitants of the Caribbean Colombian coast have great expectations for development in the selected region, since economical zones and natural systems of recognised importance are found. These are e.g. Coveñas' maritime oil terminal, Tolcemento's Industrial Port, La Caimanera wetland, systems of marshes and swamps of Cispatá's Bay, Delta of the Sinú River and Fuerte Island. Because of the strategic location of the Morrosquillo's Gulf on the Caribbean Sea, it has given origin to a process of consolidation in economic terms and services in the territorial area through time. These characteristics have determined the importance of the region in relation to development activities (port, tourist and fishing activities among others).

The SLR impact in the Morrosquillo Gulf was analyzed for both an optimistic socio-economic scenario (low social conflict, high rate growth GDP, constant population growth) and a pessimistic one (high social conflict, low rates of consumption and inversion, low population growth rate).Table 2.2 show the affected population for both cases and the proportions of the impact in the socio-economic sectors.

Table 2.2 Estimated effects of SLR in the Gulf of Morrosquillo.

Year	Population affected	Agriculture (%)	Aquaculture (%)	Cattle (%)
	Optimistic scenario			
2030	24370	94	3	3
2100	44796	32	46	22
	Pessimistic scenario			
2030	23940	94	3	3
2100	53270	32	46	22

As it is shown on Table 2.2, the socio-economic impacts measured on percentage do not demonstrate differences between the optimist and the pessimist scenarios, due to the assumption of maintaining constant the participation of the economic sectors. Nevertheless, in absolute terms, there are changes among scenarios in the temporal horizon.

In spite of these results the affected gross income is reduced 20% for the optimistic scenario in comparison to the pessimistic scenario for the year 2030. This same analysis shows a 59% lower gross income in the pessimistic scenario compared to the optimistic scenario in 2100. As an example, Table 2.3 indicates the changes in the uses of soil at an SLR of 30 cm.

Table 2.3 Changes in the uses of soil, Gulf of Morrosquillo.

Effect Type/response	Actual Use (km^2)	Area lost w/o SLR	Growth rate area actual use	Future use	With 0.3 meters of SLR	Land loss% with 0.3 m SLR
Aquiculture	5.3	0	2.2%	10.3	10.3	0.2%
Agriculture	61.7	0	1.5%	97.2	67.0	31.1%
Extractive Forest	53.8	0	-0.6%	44.5	44.5	0.0%
Cattle	128.4	0	-1.1%	92.2	91.8	0.5%
Basins conservation	0.9	0	0.0%	0.9	0.8	1.5%
Fishing	1346.6	0	0.0%	1346.4	NA	0.0%
Urban	8.7	0	1.6%	14.0	13.7	1.7%
Tourism	4.0	0	-0.2%	3.8	3.5	8.9%
Total Morrosquillo	1609	0	3.4%	1609	1589	1.3%

While studying the specific strategies and cost analysis for Morrosquillo Gulf, we found that significant measures should be taken. The main responses strategies identified are:

- The formulation of an ICZM proposal in which a more effective governance is achieved: especially integrated assessment with several administrative levels and sectors;
- More specific: implementation of a spatial planning and an ICZM proposal to combine ecological and industrial development;
- The establishment of a new regulatory measure for designing and construction of factories, houses infrastructure, roads, etc. taking into account the potential 1 m SLR;
- A road protection against erosion between Tolú and Coveñas by reducing wave impact e.g. by the construction of a marine reef or magroves;
- Local research studies on sediment dynamics in the Morrosquillo Gulf;
- Implementation of a drainage system for rainwater at the urban area of Tolú;
- A management plan for protection and restoration of river basins;
- A plan for managed (population) retreat (especially for Tolú);
- The restoration of the sediment dynamics of the Sinú River;
- The formulation of mangroves conservation plans;
- The elaboration of a strategy for aquifers protection against salt intrusion;
- The maintenance and construction of dikes.

Most important, the implementation of these measures will result in a more effective governance in the region permitting the appropriated use of resources in the definition of critical paths to reduce the impact of enhanced erosion due to an SLR.

2.3.4 Experiences and lessons learned

One of the most frequent recurrent problems during the development of the project was the lack of relevant, sufficient and reliable information, from which to produce an analysis and apply a common methodology. Many assumptions were required to supply the information gaps or make useful the scarce available information. For this reason, the action plan developed included a section related to information gaps that outlined areas where more research was required.

We found that information of two basic types in Colombia was lacking: general information on the actual distribution of the socio-economic activities on the necessary scale of applicability. Secondly general geographic information of the necessary scale was lacking.

The current lack of information only allowed a tentative approximation of the potential impact of SLR. Next to the lack of necessary information, existing information was not always available and some communication barriers existed between researchers, institutes and information sources (demonstrating the general need of integration and collaboration between administrative units).

The action plan outlined those information gaps together with actions/projects proposed to overcome such deficiencies. It is important to point out that some of the activities proposed had already started. Until now not enough historical data have been gathered that enabled yet comparison to study the impact.

Although the action plan was focused on information gaps, there were other aspects that involved information management and which represented a significant problem as well; (awareness of the) availability of existent information, incompatibility between information systems, lack of articulation, overlapping between entities that produce information, and technical limitation to produce information.

Information sources for the project included research institutes, city councils, private and public universities, territorial authorities, public libraries and consulting firms. As a result, it was a large bibliographical base that can be analysed in more detail to complement the information presented and for further contributions.

2.3.5 Follow-up research

In the future, we want to incorporate research proposals that cover the subject of SLR (impacts, vulnerability and adaptation) into the National System of Science and Technology, bringing the opportunity of more detailed knowledge of SLR impacts on particular regions. A second goal is to produce inventories on the national and regional investigation capacity related to vulnerability and adaptation capacity of socio-economic systems and natural ecosystems to SLR. In this sense, the importance of natural land creating processes (e.g. mangroves or inter tidal areas) will be acknowledged and studied. We will encourage the organisations responsible for National cartography to give appropriate attention to studies related to detailed cartography on coastal areas, starting on critical areas and ecosystems. We will also aim for the creation of a scientific base to generate knowledge on the marine and coastal ecosystem structure and functioning. It is very important to strengthen studies on coastal geomorphology, and strengthen the articulation between the National Environmental System (SINA) and the National System on Science and Technology - Marine Sciences program. This effort will result in the improvement of the information supply in the national information accounts. Hence, related statistics can be applied to productive sectors, articulate inter-institutional efforts for the creation of scenarios and develop research proposals aimed at identifying, evaluating and prioritising adaptation options related to climate change.

We expect that consolidated monitoring and alert nets on environmental and socio-economic variables identified as critical indicators of SLR will be designed at the Ministry of Environment by 2005, establishing and standardising environmental indicators on the ecosystems and marine and coastal resources. It will also state environmental and socio-economic monitoring of coastal resources to follow SLR.

We found that it is critical to develop an integrated system of coastal information exchange and process related to SLR in particular at the national level. Such a system would decrease the risks associated with climate change. Also important is the development the National Oceanic and Coastal Information System established by the National Environment Policy for Sustainable development of Oceanic, Coastal Zone and Insular Spaces (PNAOCI). This information system would serve as the baseline information to develop plans, programs and projects related to sustainable development of the rural oceanic, coastal and marine areas. In addition, it would help to incorporate that essential information for reducing vulnerability to SLR into the Oceanic and Coastal National Information System.

2.3.6 Policy implications

In general, the policy implications would be that the sector-oriented planning will take SLR into account, especially in those sectors directly involved in developing coastal areas, such as ports, fisheries, aquaculture, tourism and urban planning. Departments and national entities would include aspects related to vulnerability assessment, socio-economic impacts in their sector in their strategic management plans and their sectarian indicative plans.

The PNAOCI identified seven economic sub-sectors and proposed specific actions in each one of them, this being the basis for adaptation programs and preparation for the sectarian areas. Also, the National Plan for Disaster Attention and Prevention (PNPAD) established the need to include different types of risks in the sector-oriented planning risks.

The Ministry of Environment in the National Program will take SLR into account for Coastal Zones Management. Even though in the rural areas institutions and legal instruments already exist, the program is still emerging in these areas and urgently requires integration to strengthen the institutional mechanisms for its implementation. Our goal is that SLR and climate change risks will have to be included in any planning instrument or policy adopted by the governmental entities locally, regionally or at national level. Solutions must be participative and many levels of coastal management will be included, not only those institutions responsible of risk mitigation and attention.

We expect that at the municipal level Territorial Land-Use Plans will incorporate the subject of disaster prevention as a general rule. SLR and ‘climate variability’ in general has not been included in any of the local spatial plans because of the lack of awareness, experience and knowledge regarding the subject in the rural areas. Furthermore, references to and data collection of particular events such as hurricanes, flooding, tsunamis or El Niño phenomenon are limited. This exercise conforms the first step to improve that situation.

One of the first actions will be to define the desired functions of the coastal zone. Proposals for such projects will be formulated by INVEMAR as soon as possible with the support, participation and compromise of regional and local entities. Such projects will articulate and take into account the guidelines established by the PNAOCI, the PNPAD and their correspondent documents from the National Council of Economic and Social Policy commissioned by their programs and strategies as well as new funds.

It is well known that the best prevention and mitigation tool that can be applied to any natural disaster is to build capacity and increase knowledge and understanding in communities and populations affected or at risk. SLR is no exception. However, there are no articulated programs for SLR in the educational system, although there have been some initiatives at the local level. The vulnerability of cultural and social aspects was ranked high due to the low quality of life in most of the Colombian coastal areas. The armed conflict affects a great proportion of the population and influences almost all its economic activities. However, there is a need to educate and train the population to make them aware of climate change and related SLR effects by all possible means, using formal and non-formal education and with the support of research institutes, the Ministry of Environment and the Ministry of Education. We have also outlined the need to train the media on the coverage of scientific news and news related to natural phenomena and disasters. Two main areas of action have been included in this line:

- Public awareness: access of information needs to be given to the society. People have the right to know about the threats and vulnerabilities that exist in the places where they live or where they invest capital;
- Public participation: stakeholders, actors and population of the coastal areas who benefit from their resources will be considered in any SLR mitigation or adaptation program.

Coastal communities’ participation will be enhanced using the present social structures. There is already legislation in Colombia’s Pacific coast that promotes citizens’ participation. Instruction and, education need to cover all of the coastal population, including big cities and small villages, no matter how distant they are. The PNAOCI proposed a program involving communities in the education and participation process, in actions related to prevention and mitigation of sea level change. Such a program suggests an active interaction between users, communities and ethnic groups in the coastal management process by means of education, participation, land planning and decision-making processes. There is a need to include more sea-related information in secondary education programs aimed to create a future conscience and support of the general public to coastal and marine territories. In addition, there will be more information on the topic of ‘sustainable development’ both for ICZM as for all territorial use in Colombia.

It is also important to improve negotiation and management capacities of Colombia with international organizations that deal with climate change and sustainable development in general. The Ministry of Environment and the Foreign Relations office participate actively in the UNFCCC. However, there is a need to continue negotiating international funding for research projects as well as for response strategy projects.

Furthermore, the need has been identified to intensify the co-operation with neighbouring countries to develop projects for the regional evaluation of the SLR vulnerability, adaptation and mitigation possibilities. In that aspect, INVEMAR and the Ministry of Environment are already contacting neighbouring countries for developing ICZM processes based on the Colombian experience.

2.3.7 Conclusions

The main purpose of the project was to define the vulnerability of the Colombian Pacific and Caribbean coastal areas, for SLR and climate change. In addition the ability to define and execute adaptation measures of the bio-geophysical, social-economic and country capacity ('governance') was determined. , The ultimate goal of the study was to better prepare Colombia for such an event. This goal was achieved.

Furthermore, an elaborated information base line was generated which reflected the actual situation of the Colombian coast. The project developed a preliminary qualitative model that permits the detection of changes in the coastal marine ecosystems caused by an eventual SLR, as well as predicting potential inundation zones and other possible scenarios. In the international field, the information provided by the study was used for the preparation of the National Communication to the UNFCCC, as part of Colombia's commitments to this international agreement.

The results lead to the conclusion that Colombia's natural systems are highly vulnerable to SLR, and that there are great gaps in knowledge of the ecosystems' condition, possibilities for recuperation and adaptation capacities. Furthermore, the analysis shows the high vulnerability of the Colombian coastal zone, regarding population affected, economic costs of possible impacts of SLR and response strategies (in terms of GDP) in the affected areas.

The analysis indicated seven critical areas: the Caribbean islands San Andrés, Providencia and Santa Catalina, the major cities and economic zones on the Continental Caribbean: Cartagena, Barranquilla, Santa Marta and Turbo, and the major cities and economic zones on the Pacific coast: San Andrés de Tumaco and Buenaventura. Taking future planned developments into consideration, another potentially critical area would be the Morrosquillo Gulf.

The critical municipalities and their correspondent coastal environmental units will be studied in detail followed by vulnerability assessment projects that would continue as a result or consequence of this project. These follow-up projects will be developed on a greater scale, with greater data resolution and focus on smaller areas; resulting in more concrete adaptation, prevention and mitigation measures.

With the current information, it was not possible to approach adaptation measures on a national level. For each critical area, optimal and applicable solutions will be developed according to its characteristics, needs and conditions. Financial, costs and benefits analysis on mitigation and adaptation measures will be quantified for each specific site.

Finally, this investigation was responsible for offering information to the National Environmental System which supports the implementation of the National Environmental Policy. Hence, it increased the awareness of the general public regarding the hazards related to the sea level rise.

Main products

INVEMAR (2003a). *Def. Vul. of Bio-geophys and Soc.-econom. Sys. due to SL change in the Col. CZ and adapt. meas*. Informe Técnico No. 1 Delimitación del área de estudio, Instituto de Investigaciones Marinas y Costeras José Benito Vives De Andréis (INVEMAR), Santa Marta, 79 pp.

Netherlands Climate Change Studies A Program (NCCSAP): Colombia. Definición de la vulnerabilidad e los sistemas bio-geofísicos y socioeconómicos debido a un cambio en el nivel del mar en la zona costera colombiana (Caribe continental, Caribe insular y Pacífico) y medidas para su adaptación.

INVEMAR (2003b). *Def. Vul. of Bio-geophys and Soc.-econom. Sys. due to SL change in the Col. CZ and adapt. meas*. Informe Técnico No. 2 Caracterización e Inventario, Instituto de Investigaciones Marinas y Costeras José Benito Vives De Andréis (INVEMAR), Santa Marta, 474 pp.

INVEMAR (2003c). *Def. Vul. of Bio-geophys and Soc.-econom. Sys. due to SL change in the Col. CZ and adapt. meas*. Informe Técnico No. 3 Definición de escenarios, Instituto de Investigaciones Marinas y Costeras José Benito Vives De Andréis (INVEMAR), Santa Marta, 41 pp.

INVEMAR (2003d). *Def. Vul. of Bio-geophys and Soc.-econom. Sys. due to SL change in the Col. CZ and adapt. meas*. Informe Técnico No. 4 Evaluación de impactos, efectos y respuestas del sistema natural, Instituto de Investigaciones Marinas y Costeras José Benito Vives De Andréis (INVEMAR), Santa Marta, 104 pp.

INVEMAR (2003e). *Def. Vul. of Bio-geophys and Soc.-econom. Sys. due to SL change in the Col. CZ and adapt. meas*. Informe Técnico No. 5 Estrategias de Respuestas, Instituto de Investigaciones Marinas y Costeras José Benito Vives De Andréis (INVEMAR), Santa Marta, 86 pp.

INVEMAR (2003f). *Def. Vul. of Bio-geophys and Soc.-econom. Sys. due to SL change in the Col. CZ and adapt. meas*. Informe Técnico No. 6 Definición de la vulnerabilidad, Instituto de Investigaciones Marinas y Costeras José Benito Vives De Andréis (INVEMAR), Santa Marta, 41 pp.

INVEMAR (2003g). *Def. Vul. of Bio-geophys and Soc.-econom. Sys. due to SL change in the Col. CZ and adapt. meas*. Informe Técnico No. 7 Plan de acción, Instituto de Investigaciones Marinas y Costeras José Benito Vives De Andréis (INVEMAR), Santa Marta, 57 pp.

2.4 Ecuador

Hernán R. Moreano[16]

2.4.1 Introduction

The Low Guayas River Basin (LGRB), located in the Southwest of Ecuador, is the most productive area of Ecuador. It is an important area for agriculture and aquaculture, which are the leading export products, together with oil. The contribution to of this region to the GDP is 20 billion US$. Agri- and aquaculture provide direct and indirect jobs to 3.2 million people on a total population of 12.1 million. The inhabitants of the basin live mostly concentrated at Guayaquil (2.2 millions), Ecuador's major port and economic capital. Besides agriculture, the area holds a mangrove ecosystem of 120.000 ha and a estuarine water body of 5100 km^2. These are associated with the Guayas River and Estero Salado Estuaries, connected with the Gulf of Guayaquil through the Jambeli and El Morro channels.

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The climate of Ecuador's Coastal Zone is determined by the position of the Inter Tropical Convergence Zone (ITCZ), the offshore water masses distribution and climate variability events such as El Niño Southern Oscillation (ENSO). All three are responsible for flooding of the low-lying areas in the basin and for sea level rise within the estuaries. The last ENSO event of 1997 - 1998 lasted 10 months and impacts were valued US$ 2.6 billions in the entire coast. This is a rough estimate made by the Latin American and Caribbean Economic Commission (CEPAL, 1998).

Climate change is a risk for Ecuador and its coastal zone and especially the LGRB. In 1997 the Ministry of Environment and the Netherlands Climate Change Studies Assistance Program agreed to conduct a vulnerability assessment study for precipitation and sea level rise in this area. Four Ecuadorian institutions carried out the study: Instituto Oceanográfico de la Armada (INOCAR) for sea level rise in the estuaries, Instituto Nacional de Pesca (INP) for impacts on mangrove ecosystems, biodiversity and the shrimp industry, Instituto Nacional de Meteorología e Hidrología (INAMHI) for precipitation assessment of the low basin hydrographic systems and Instituto de Planificación Urbana y Regional (IPUR) of the Catholic University (UCSG) for social and economic impacts in the study area. The vulnerability assessment was successfully completed eighteen months later (GRUPO BASICO, 1999) and its products and results were presented at an international workshop held in Guayaquil in June 1999. In addition, the results were used as input in The National Communication prepared by Ecuador in 2001.

The problem definition

Under an integrated vision of resources, environment, social and economic issues, a vulnerabiliy assessment study of the Low Guayas River Basin to climate change was conducted. In this study precipitation, sea level rise and ENSO events were considered as a matter of Climate Variability (CV) and were taken into account.

The goals of the study included:

- To assess the possible impacts of climate change on the present and future situation of coastal resources and their consequences on economic and social matters;
- To identify possible attenuation measures and projects that will accommodate with such measures;
- To develop planning tools for impact assessment on long term changes of resources and their use;
- To contribute to the establishment of an institutional structure for management of Ecuador's Coastal Zone;
- Capacity building in Integrated Coastal Management;
- To contribute to the National Communication of Ecuador.

2.4.2 Approach

The vulnerability assessment study was carried out using the seven steps as described in the Vulnerability Assessment of Coastal Areas to Sea Level Rise, prepared by the IPCC in 1991 (IPCC, 1991, 1992; Carter *et al.*, 1994; see also Section 1.5.2). Steps 2 through 4 were made by the project co-ordinator and the working groups of institutions involved in the project, while a series of workshops was organised to define the boundaries of the study area, the climate scenarios for precipitation and sea level rise, formulation of response strategies, results assessment and a proposal of a long term structure to manage the Low Guayas River Basin.

The common methodology focused on the assessment of the impact on the natural and socio-economic system as a consequence of the physical effects of sea level rise and on the effects of response strategies. The vulnerability assessment starts with a delineation of the study area and specifications of sea level rise boundary conditions, followed by an inventory of the study area characteristics and the identification of relevant development factors related to production activities, capital investment and natural values.

After completing these three initial steps, an assessment of physical changes and the natural system response follows, which includes: morphological development of the shore line, water levels and changes in salinity. Then, the response options are formulated with an estimate of their cost and an assessment of their effects, considering scenarios that represent cases showing the cost of the response options in each economic scenario (with and without development). The vulnerability assessment ends with assessing the susceptibility of changes imposed by sea level rise and related socio-economic impacts, followed by actions to develop a long term basin management plan based on integration, and participatory decision making.

2.4.3 Results of the vulnerability assessment

The study area was selected because of its sensitivity to sea level rise. Impacts of flooding are already felt and these impacts could increase in the future as a result of sea level rise and changes in precipitation. The perimeter is 630 km and encircles an area of nearly 15,000 km^2 that holds 200,000 ha of agriculture fields of banana, rice and sugar cane and a population of 3.4 million people, mostly concentrated at Guayaquil. This city port is located at the upper branches of the Guayas River and Estero Salado estuaries where a series of islands and archipelagos are distributed which are covered by mangrove forest and shrimp ponds. Further south, Machala and Puerto Bolivar are the main city and port (INP, 1998). See the map of the study area (see also Figure 2.5).

Waters of the estuaries are tide driven and their volume depends on the behaviour of ocean currents at the eastern pacific, on precipitation, fresh water river inputs caused by the southward motion of the ITCZ (Inter Tropical Convergence Zone) and by warm ocean water masses driven by surface currents or by the ENSO event.

The geometry of the estuarine systems and the differences in phase with sea level make a complicated pattern of circulation, especially near the mouth area where both estuaries are connected. Horizontal salinity gradients are noticeable in the Guayas River estuary because of the fresh water inflow that fluctuates during the seasons. The maximum range of the salinity intrusion is as far as Guayaquil, it does not penetrate further because of the regulated permanent flow of the Daule River controlled by the Daule - Peripa Dam further north. Vertical gradients are almost negligible and both estuaries fall in categories 1a and 1b in the Hansen and Rattray (1966) circulation and stratification diagram.

The tidal prisms for the Guayas and Estero Salado estuaries are 4.4 billions, and 1.2 billions cubic meters respectively. The flushing time for the Guayas Estuary is between 8 to 13 days (Palacios, 1989) and could be less in periods of high river flows associated with El Niño. The Estero Salado upper reaches located west of Guayaquil in the contrary do not have fresh water inflow and flushing time is longer than in the Guayas. Going southward and closer to the mouth, the water exchange with the ocean and with the other estuary shortens the flushing time.

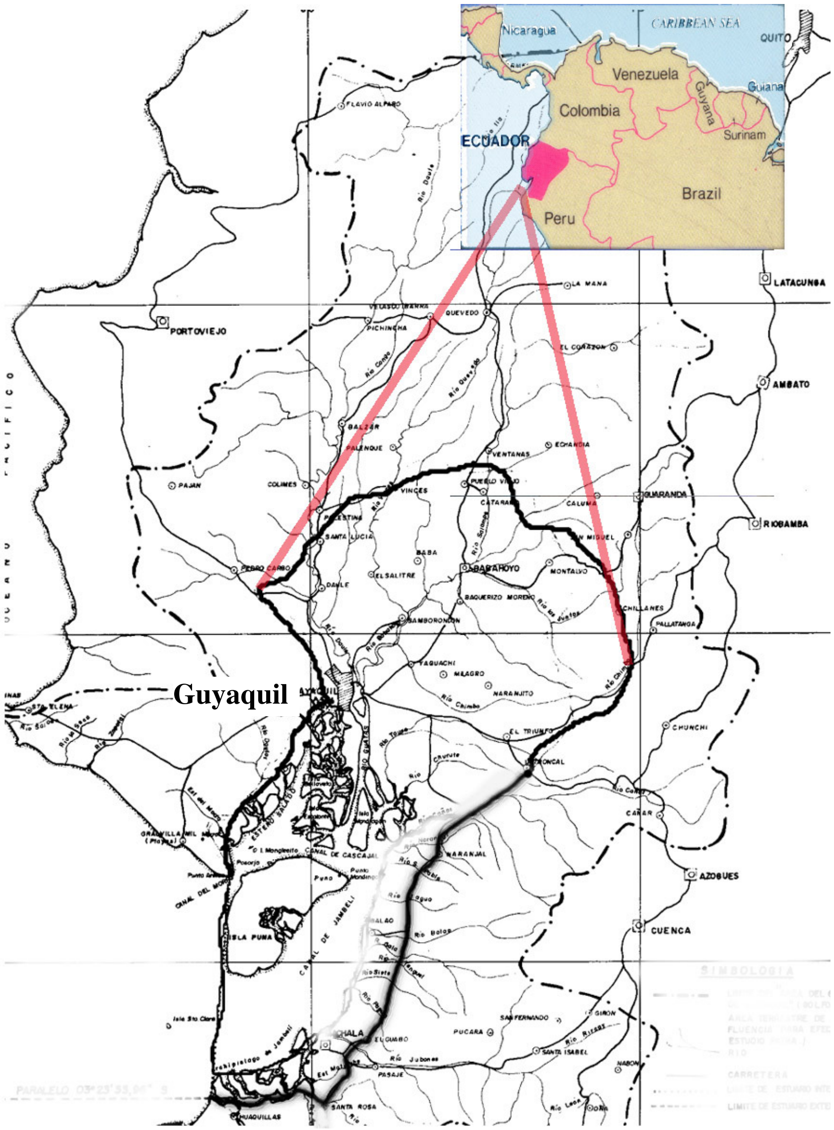

Figure 2.5 Map of the Study Area in Ecuador. The thick black line shows the boundaries of the study area.

All three hydrographic systems are responsible for sediment transport and fresh water inflow into the study area. Calculated numbers by INAMHI are in the order of 11.2 to 22.5 millions of metric tons per year and an overage annual flow of 1355 m^3/s. The main contribution comes from the Guayas hydrographic system, which makes nearly 80% of the total.

The economic situation

The economy of Ecuador is marked by a huge external debt of US$ 16 billion, an annual budget with lack of resources to invest in productive sectors, low foreign investment because of lack of guarantees in the political, economical and judicial systems and high inflation and interest rates. Unemployment is about 18% and probably higher in the study area as a consequence of the last ENSO event, growth of the GDP was 0.8% in 1999 and there was a contraction in 1999 by about 6% because of political and economical instability.

Two sectors are responsible for one third of incomes for exports: agriculture and aquaculture. Both take place in the study area. Experts expect both sectors to grow during the 21st century, but this will require new technologies and subsequent investments to obtain a higher degree of product diversification and differentiation (IPUR, 1998).

GDP for the country in 1998 was US$ 20 billions and is estimated to be US$ 9 billions for the study area. Ecuador's total population amounts 12.5 million, of which 3.4 million live in the LGRB live. The population a growth rate is 2.2% per year.

Two socio economic scenarios were considered: no development from the year 1998 and development for the year 2010. These were used to make calculations on population growth and to assess the cost on capital goods impacted by CC.

Climate scenarios

Several climate scenarios were established, and after discussions among institutional experts during the initial workshop hold at Guayaquil at the end of 1997 (See Box 2.2) it was agreed to work with the scenarios included in Table 2.4.

Table 2.4 Scenarios for the vulnerability assessment study for 2010.

Scenarios	Conditions
Basic (SLR 0)	No changes in sea level, air and ocean surface temperatures and precipitation.
Moderated (SLR 1)	Sea level rise of 0.3 m, with an increase of 1°C in air temperature, Sea Surface Temperature (SST) anomalies less than 1°C and a 15% reduction in precipitation.
Severe (SLR 2)	See level rise of 1.0 m, with an increase of 2°C in air temperature, SST anomalies over 2°C and a 20% increase in precipitation.

The climate variability associated with El Niño was considered in all three scenarios, because it generates see level rise of the order of 0.2 m and 0.5 m for moderate and extreme events respectively. These values are within the time series used to calculate the return periods of 10 and 100 years. The same is true for precipitation, air temperatures and Sea Surface Temperature (SST) where values are from 50% to 80% precipitation increase, and >2°C anomalies in temperature for moderated events and 300% to 600% and >4°C anomalies for extreme ones.

As the study area is not affected by ocean storms, hurricanes and tornados, the climate scenarios do not consider data related to these events.

Box 2.2 Choosing climate scenarios.

Outputs of most Global Climate Models (GCM) are in degrees Celsius of air temperature variation and percentage of precipitation below or above average. Unfortunately, climate in the global context and particularly in the coastal zone of Ecuador is not only related to changes in the atmosphere, but also to changes in the offshore water masses driven by surface currents. These in turn are coupled to the wind driven circulation patterns on the Pacific Ocean. One of the problems for the Ecuadorian group of experts dealing with the VA study was to find a way to match the scenarios chosen by INAMHI (1998) from GCMs with the behaviour of water masses and surface ocean currents in the Eastern Tropical Pacific Ocean.

The proposed INAMHI scenarios were as follows (values for 2010 compared to 1998):

Scenarios	Air Temperature	Precipitation
1	+1°C	-15%
2	+2°C	+20%
3	+1°C	+20%
4	+2°C	-15%

After discussions, the working group of experts agreed that scenario 1 matches with the moderate scenario for the Vulnerability assessment study, assuming an increase of water transport of the Humboldt coastal current but keeping SST anomalies <1°C, air temperatures will increase by 1°C, precipitation will be less than overage by 15% and there will be and increase of sea level of 0.3 m. Meanwhile scenario 2 matches with the severe one, assuming an offshore warm water mass which source is the Panama Basin and it is driven southward by El Niño current; SST anomalies will rise over 2.5°C, air temperature will increase at least by 2°C, precipitation will be above overage by 20% and sea level rise will be 1.0 m. Scenarios 3 and 4 are far away from reality because with a cool ocean is impossible to have a 20% increase in precipitation and with a warm ocean is impossible to expect a decrease in rainfall.

Results

The semidiurnal tidal wave that gets into the estuaries is deformed by the difficult geometry and hydraulic friction, at the point that tide range is 1.5 m (neap) and 2.3 m (spring) at the mouth, whereas at the head those values increased to 2.5 m (neap) and 3.6 m (spring); this means of course that the level of flooding is higher at the head than at the mouth (INOCAR 1986), for this reason, the estuaries were divided in five sectors to apply levels of flooding accordingly to location and climate scenarios (INOCAR 1999). Although for Guayaquil the high values are applicable, average values were taken instead to establish the impact zones for each scenario. These zones are indicated in Figure 2.6.

Capital lost, at risk and at change were considered for each of the impact zones for the 1998 and 2010 scenarios. Capital lost include all flooded land and coastal habitats such as mangroves, shrimp ponds, banana, rice and sugar cane plantations, beaches and urban areas of Guayaquil, Machala and Puerto Bolivar. Losses for SLR1 are in the order of 10% to 14% of GDP, but for SLR2, they go up to 12.5% and 18.5% for 1998 and 2010 respectively.

Major loses are from mangroves and sugar cane plantations and associated industry. Mangrove will almost disappear in the SLR2 scenario, this represents a loss of over one billion US$ without considering associated biodiversity, CO_2 fixation and the role of this forest in the estuarine ecosystem. Although the cost of the response strategy is high, it is distributed through time, which allows for the investment to keep this natural system alive.

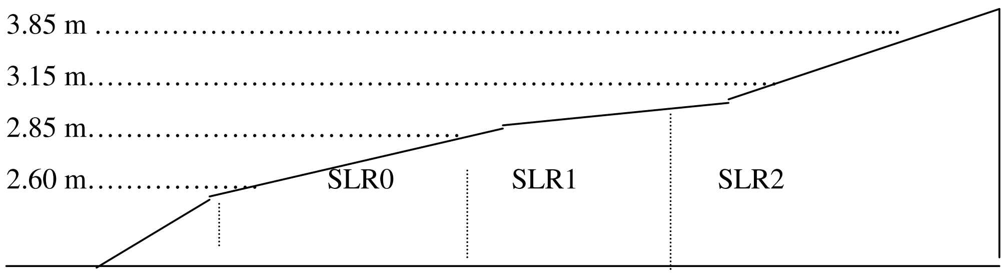

Figure 2.6 Impact Zones related to averaged levels of flooding for each climate scenario.

In the aquaculture industry, the location of the ponds was improved after El Niño in 1982-1983. Hence the impact of flooding will be less severe. Furthermore, the increase of the sea surface temperature is favourable for shrimp grow, increasing production and productivity. This was the case for 1997-1998, where shrimp exports were highest ever. After 1998 the export collapsed dramatically to 30 percent of the 1998 levels because of the white spot virus.

Values at risk include people and capital values facing the probability of flooding in the same areas. It is estimated that between 17,000 and 370,000 people have to be evacuated and 75,000 to 2,000,000 people are at risk. Capital values are estimated one to three times the GDP for the different scenarios. Values at risk include mostly financial damage to each of the sectors and values amount up to three times the GDP in the worst scenario.

Fresh water availability for all three scenarios is in the order of 35 to 45 billion m^3/year, but these numbers increase substantially during an ENSO event and specially during the extreme ones which last ten months. Water demand by population, irrigation and industry in the same scenarios are 6 to 8 billion m^3/year, so the basin has plenty water resources. However, there is a need for conservation of these resources for during the dry season. This is programmed in the basin development project through the construction of dams.

Two response strategies were considered for the vulnerability assessment study:

1. **No Measures**: No actions are taken at all to face sea level rise and changes in precipitation due to climate change. Of course, the costs of this strategy are zero, but large costs associated with damage are very likely to be incurred.
2. **Total Protection**: Adaptation measures are considered and implemented to reduce losses and risk in each impact zone in order to protect people and capital values distributed in each zone. The first adaptation measure that could be taken in the LGRB to decrease the effects of changes in climate and variability is the implementation of the development plan for the basin made by CEDEGE (1992). Coastal defences are considered for shrimp ponds, beach nourishment for the Jambelí beach and hydraulic refills for urban areas. The vulnerability assessment study considered that the development and integrated management plan of the study area are responsibilities of the Steering Committee of Provincial Development, created by the Decentralisation in Social Participation Act of 1997. The Committee is the central authority for planning

and evaluation, while the implementation of projects and activities will be the responsibility of local institutions such as counties or municipalities. These have the capacity to put plans that are agreed on with local stakeholders, into action. The scientific community is represented in specific working groups of the advisory board to provide the necessary social, economic and environmental information for planners and project makers.

The combination of development and integrated LGRB management gives the study area a particular strength, because each component works independently and within its own framework. They are all interdependent because they support each other with delivery of data for planners and project makers while these in turn contribute by supplying resources and asking new questions to the researchers.

2.4.4 Experiences and lessons learned

The Basic Group coordinated the work of experts from Ecuadorian research institutions. This showed that knowledge and data were available to carry out the project. It was possible to design adaptation strategies to reduce climate change and climate variability impacts on the basis of a multidisciplinary discussion that allowed integration of use and experience of participants. Unfortunately, the Basic Group finished its work in 1999, just a few months after the study was completed. Since then, matters related to climate change have been the responsibility of the Coastal Climate Change Co-ordinator.

The methodologies and models used provided valuable results on sea level rise and river flow predictions. The involved experts were pleased to transfer the know-how of these techniques and fortunately there was enough data to feed the models. The model outputs appear to be reliable. After finalising the project, the working group did not have the opportunity to proceed with a new study with a more multidisciplinary approach. The people working on the project learned a lot during the 18 months period, not only about technical matters, but they also learned more social skills and teamwork. These important achievements are kept alive by the work of the Coastal Climate Change Coordinator.

The group of experts agreed that the seven steps to the assessment of the vulnerability of coastal areas to sea level rise were coherent and understandable. The difficulties arose when discussing scenarios and matching outputs of General Circulation Model with the offshore local conditions (see Box 2.2). Data to delineate characteristics of the natural system was available except data that related to erosion and accretion processes, subsidence values and groundwater sources within the estuary. It was not the same with that of the socio economic system: especially the cost of the unit area of natural ecosystems as mangroves and productive sectors as rice, banana, sugar cane and shrimp ponds were difficult to find. This is caused by the difficulty of valuing ecosystems, and the great differences in infrastructure and technology that each farm uses. After analysis and discussions, it was agreed to use average values, which allowed the continuation of the vulnerability assessment study.

The response strategies were easy to identify, because most of these strategies were considered in the Low Basin Development Project prepared by CEDEGE. The main problem was to estimate the cost of the remnant infrastructure to be built in the future because of the economical instability of the country.

In the last decade, governments in Ecuador initiated a decentralization process and there is an interesting legal framework to manage coastal zones or river basins, so, it was not a problem for the group of experts to find a way within such framework to deal with the management of the LRGB. The main problem is that the political motivation for making decisions is lacking and therefore the proposal has not been approved.

2.4.5 Follow-up research

Some months later after the vulnerability assessment was completed, impact assessment and adaptation strategies were reviewed by the same group of experts. Once the final report was ready, the vulnerability assessment study findings and policy advices were used in the National Communication. Since then, a series of seminars and workshops have been held along the coastal zone to increase the awareness of local authorities, stakeholders, municipalities and civil society about the climate change risks and results of the vulnerability assessment study. Funding for this work was provided by the responsible Ministry and by international donor agencies.

The LGRB is not the only estuarine area in Ecuador, there are three medium and seventy small sizes estuaries associated with river basins and coastal valleys, city ports and beaches. On the Galapagos Archipelago the research results of the climate change studies need to be communicated to the local stakeholders. This will help to empower them to implement adaptation strategies and to strengthen policies already included in the National Communication. These policies were drawn by the government to reduce the vulnerability to climate change, as described under article 3 of the UNFCCC.

Many universities and faculties have already included the issue of climate change in the undergraduate and postgraduate curriculum, through seminars and workshops were participation of both the national and coastal coordinators are always welcomed.

2.4.6 Policy implications

The vulnerability assessment study did lead to the following policies to reduce the vulnerability of the LGRB to climate change.

Within some years the infrastructure of dams, irrigation and bypass channels, projects of transfer of water, hydroelectric plants and drainage systems designed by CEDEGE and PREDESUR described in the development plans for the study area will be completed.

The following project of CEDEGE were completed:

- Bypasses of the Bulu Bulu and Chimbo rivers;
- Irrigation and drainage system of the Catarama River;
- The transfer of water from the Daule River to the Peninsula de Santa Elena;
- The Daule Peripa to La Esperanza and Poza Onda project;
- The 210 MWatt hydroelectric plant.

And the following PREDESUR project were completed:

- Various drainage and irrigation projects related with the Marcabelí Dam in El Oro province. The infrastructure will reduce the risk of the study area to climate change and climate variability events like El Niño.

The conservation of mangrove forests as an instrument to conserve the estuarine environment and to preserve of the biodiversity associated with these ecosystems is implemented in the area. Mangrove cuttings are reduced as a result of a series of new regulations issued by the government through the Ministry of Environment. Cutting these forests now is a crime punished with fines and jail. There is a better control by authorities lead by the Navy (Coast Guard and Port Captains) who work together with the 'Law Enforcement Unit', The local communities are also empowered to defend the mangrove forest and its resources.

The shrimp pond owners in the estuaries learned during the last El Niño event new techniques to make the levees stronger to reduce risk to SLR provoked by El Niño and of course this will be useful for SLR as a result of climate change.

Adaptation strategies should consider integrated basin management as a beachhead for the development of the studied area. The Ecuadorian government has applied integrated basin management in six coastal areas since a decade. This is done through the Coastal Resources Management Program, where civil society, combined with the public- and private sector have organised themselves. Through the program they together coordinate the decisions on distribution rights, obligations and rights for the use of the shared coastal resources. This is implemented through the preparation and formal adoption of a Management Plan for each Special Management Zone, but it is not functioning yet.

The Decentralization and Social Participation Act is supporting this policy, because it leaves the responsibility to make decisions on their own development to the local civil society and stakeholders. On this basis many municipalities have prepared Management Plans, drawn up through local participation. These management plans have clear goals and strategies on issues related to climate change. Furthermore the Decentralization and Modernization Act transfer competences from the central government to local the local level. For example environment has been included into the Counties agenda. Furthermore by the Environmental Act, Counties must create within its structure an Environmental Management Unit (EMU).

The methodology of the seven steps allowed the definition of the problems of the LGRB to climate change and supported them with background data and analysis. Then some policy options were developed and criteria and weights were established to evaluate these options. This helped to make decisions based on best policies, which will be adopted and applied in the study area. The best policies defined face both climate change and climate variability.

2.4.7 Conclusions

The vulnerability assessment showed the vulnerability of the LGRB to climate change and climate variability. The worst-case scenario (SLR2) indicates that capital at risk and capital lost together amount three times Ecuador's GDP of 1998. Adaptation measures to reduce the costs of the impacts of climate change amount to 10 to 20 percent of the 1998 GDP. That is if the measures are taken now, the cost will increase substantially if they are left for 2010. The cost – benefit relation is favourable to implement the measures now. The main constraint for implementing response strategies for sea level rise and precipitation changes is that the economy of Ecuador cannot bear the investments.

The Coastal Resources Management Program, a governmental structure in charge of applying Integrated Coastal Management (ICM) along the continental coast of the country, is aware of climate change matters and the vulnerability assessment committees and municipalities that work with the Program within the Special Management Zones, where ICM is applied.

The basic group, the coastal climate change coordinator and experts of participant institutions have the knowledge and experience to focus the investigations toward the issue of impacts and adaptation.

The proposed management scheme for the LGRB is based on local participation in decision-making. However, it is not function yet. This is caused by the period of political and economic instability after the research of the basic group. Later the Environmental act was approved and that obligates municipalities to make an integrated plan in cooperation with the undersecretary of Coastal Environmental Management, this is also the case for the LGRB.

Main products

CEDEGE (1992). General Plan for Development of the LGRB.

CEPAL (1998). Ecuador: Evaluación de los efectos socioeconómicos del Fenómeno del Niño en 1997 - 1998. Informe.

Grupo Básico (1999) Evaluación de la Vulnerabilidad de la Cuenca Baja del Río Guayas al Levantamiento Acelerado del Nivel de mar. Ministerio del Ambiente.- Reporte Final

INAMHI (1998). Vulnerability of Water Resources of the LGRB to Climate Change.

INOCAR (1986). Oceanographic Studies for Dredging the Estero Salado Navigation Channel.

INOCAR (1998). See Level Rise and Salinity Intrusion.

INP (1998). Estuarine Natural System - Technical Report.

IPUR (1998). Socio economical Study - Report.

2.5 Egypt

Ayman F. Abou Hadid[17] and Helmy Mohamed Eid[18]

2.5.1 Introduction

Egypt depends on the Nile River as the primary water source. Its large traditional agricultural base and its long coastline, already undergo both intensifying development and erosion. The rapid growth of the country's population, the economic stress of reliance on food imports, and the limited area for agriculture require Egyptians to find new ways to increase agriculture productivity and water resources. The Egyptian coasts extend over more than 3000 km and include coasts on the Mediterranean and the Red Sea in addition to a number of lagoons situated along the Nile delta coast and to the east of the Suez Ca-

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nal. Coastal lagoons and lakes are, in general, zones of high productivity and are extremely sensitive to disturbances (Figure 2.7).

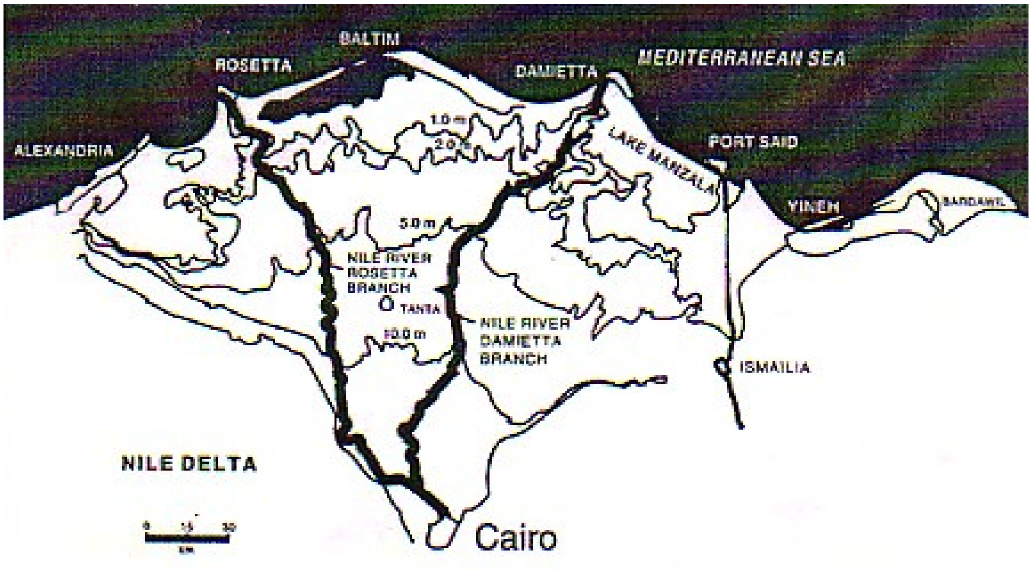

Figure 2.7 Topographical map of the Nile Delta (Nicholls, 1991).

This, combined with the country's economic situation, makes the coastal zones and water resources in Egypt vulnerable to climate change and particularly to sea level rise (SLR). Many of the deltas would be subject to inundation in case of SLR. On the global scale, significant reduction of coastal wetlands appears likely and may result in negative impacts on other resources, such as fisheries. Countries with large agricultural populations in deltas, such as Egypt, are particularly vulnerable. A decrease of the River Nile budget and flow rate (as predicted by some models), could result in an increase of the rate of erosion and salt water intrusion at the Northern Delta coast, effecting agriculture and other sectors.

These effects, and a lack of accurate up to date information on elevation and socio-economic characteristics of its coastal zone was selected for a more in depth study on the possible impacts of climate change. The study included a quantitative vulnerability and adaptation assessment covering all vulnerable areas for each of the coastal governorates of Egypt. The study also included activities to upgrade the existing Geographic Information System (GIS) by using high-resolution satellite images to accurately identify vulnerable areas and changes in sea elevation and socio-economic characteristics after adoption of the law 4/1994 (Legislation for the Egyptian Environment Protection including coasts), update land subsidence rates by installing tide gauges over vulnerable shores and upgrade the digital elevation models (DMD).

The study aimed to survey processes and problems along the coastal areas of Egypt and to define the 'degree of vulnerability' of the coastal zone of Egypt and to start discussing integrated coast zone management. Examples of coasts of varying vulnerability were discussed and possible future extension of studies to address some of the unsolved problems were identified.

2.5.2 Approach

Several general assessments of the possible impact of SLR on the Nile delta coast were carried out in the 80's and 90's (e.g. Broadus, 1986; Stanley and Warne, 1993). An SLR vulnerability assessment finalised in 1992 (Delft Hydraulics, 1992), included a preliminary assessment of socioeconomic impacts and impacts on Egypt's northern wetlands and fisheries. In one scenario, it was analysed that aquaculture development in northern lakes would have a large effect on fish production potential.

The River Nile delta of Egypt is considered one of the areas most vulnerable to sea level rise (SLR). Large areas south of Alexandria, Rosetta and Port Said are considered highly vulnerable. Rosetta city is a well-known Paranoiac and Islamic city located in the Rosetta region near the intersection of Rosetta branch of the River Nile with the Mediterranean sea, east of Alexandria. Excessive erosion rates have been observed at the Rosetta promontory tip, due to cessation of sediments after building the Assuan dam in the River Nile about 1000 km in the south. The region surrounding the city is well known foe its water logging and water bogging problems. Current problems in the coastal zone of Port Said are beach erosion, pollution, subsidence and sea level rise. Previous studies on Alexandria (e.g. Frihy et al, 1996; Emery *et al*., 1988) indicated moderate sea level rise ranging from 0.5-0.8 mm/year (See the map in Figure,1 by Nicholls 1991). Few other studies reported an uplift of Alexandria using short time series of annual tide gauge records at a rate of 0.7 mm/year due to geotectonic uplift.

The vulnerability and adaptation assessment described in this paper was carried out using the IPCC common methodology including the 7 steps method: define problem, select method, test method sensitivity, select scenarios, assess biophysical impacts and socioeconomic impacts, assess autonomous adjustments and evaluate adaptation strategies. (El-Raey et al., 1997 and IPCC, 1994; see also Section 1.5.2).

The following methodology was used for assessing baseline adaptation and future adaptation options:

1. Identify and prioritise vulnerable sectors and localities based on the country vulnerability assessment;
2. Evaluate baseline (i.e. existing and already planned) policies and measures based on technical and economic efficiency, social goals and environmental sustainability using multicriteria analysis;
3. Evaluate the baseline similarly to the impact matrix and scores;
4. Evaluate the identified adaptation options to cope with SLR;
5. Compare adaptation baseline and SLR adaptation options and identification of the effectiveness of adaptation measures.

A multidisciplinary team of researchers carried out this assessment. This method also enabled assessing adaptation capacity development with time.

2.5.3 Results of the vulnerability and adaptation assessment

The IPCC method results indicated that agriculture, industry and tourism, would be most vulnerable to SLR. However, employment analysis indicated a different order of vulnerability: industry, tourism and agriculture A more detailed assessment for the cities of Port Said and Rosetta (several other studies reported an uplift of Alexandria) indicated that, without adaptation, Port Said is at risk of significant impact on various sectors (El-Raey *et al*., 1997) while Rosetta is at risk to significant land losses and effects on historic and archaeological sites, employment and agricultural lands. The study showed that not all the coastal zones of Egypt are vulnerable to SLR to the same extent. Identified vulnerable areas along the northern coast plans included:

- Narrow sand barriers separating the Mediterranean from the costal lagoons, such as barriers of Burullus, Manzala and Bardawil lagoons;
- The flat and low-lying coastal plain (less than 2m high), such as the backshore are south of Abu Quir headland, the Manzala lagoon area, and El Tineh plain, east of Port Said;
- Deltaic coastal plain areas affected by vertical land movement (subsidence) due to sediment compaction, dewatering and tectonics.

Identified invulnerable areas included coastal plains backed by high-elevated features, such as sand dunes and carbonate ridges that would act as a natural defence system against SLR. Example include:

- The Pleistocene carbonate ridges, backing the western beaches of Alexandria and the local rocky limestone islets off the waterfront of Alexandria city;
- The rocky carbonate ridges, backing the western beaches of Alexandria and the local rocky limestone islets off the waterfront of Alexandria city, acting together to protect the low – lying areas south of the city and west of Abu Quir headland; and
- The coastal dune systems backing the coastline of Abu Quir bay, Gamasa embayment and El Tineh bay.

Areas experiencing tectonic uplifting such as the west coast of Alexandria and Red Sea probably will be less affected by the SLR than other areas.

Low-lying coastal zones experience a moving coastline, i.e. accreting beaches, even they are subsiding. This may be due to the tourism activities across the coast where new beaches were built. These areas are not vulnerable to SLR if the rate of accretion exceeds or at least balances that of relative SLR. More research is needed to identify levels of vulnerability and high risk areas. Although the length of the Nile delta is undergoing regional retreat, there are a number of localities experiencing accretion. On the whole, the eroded sand is carried along the shore eastward or locally to the west and subsequently is deposited in areas of beach accretion within saddles or embayment between promontories. Such areas are central zone of Abu Quir bay, Abu Khashaba (west of Rosetta estuary), Gamasa embayment and El Tineh bay.

The assessment showed that, without adaptation, millions of people would be at risk of loosing their homes and needing to migrate due to flooding in a 0.5 m SLR scenario by the year 2050 (Sestini,1992; Delft Hydraulics,1991; El-Raey et al, 1995). Without adaptation, the capital at risk was estimated at US$2.5 billion (at 1992 prices) under the same scenario. Additionally the estimated loss of productive land would have serious implications on job opportunities and food availability. It was estimated that 15% of the arable delta land would be subject to inundation, extending as far as 20 km inland from already existed coasts, with a 1 m ALSR scenario by 2100. Additionally land productivity would suffer due to salt-water intrusion effects up to the 2 m contour line, which is 30 to 60 km wide. This belt includes important cities such as Alexandria, Port Said, Kafr El-Dawar, Rosetta, Damietta, Mataria and Manzala (Sestini, 1992; El-Raey et al, 1995).

2.5.4 Adaptation

Adaptation baseline policies and measures are defined as the set of policies and measures already taken by various concerned authorities, and NGO to minimise adverse impacts of sea level rise from the perspective of the precautionary principle. This also includes past experience with adaptation such as technical means of enforcement, assessment and feedbacks. The RIAM software represents a comparison between baseline conditions and options for adaptation for a particular sector at a particular location (Nicholls, 1995). Aggregation of such results is also possible.

The final results could be summarised here in the following points:

1. The most severely impacted sectors are agriculture, industry and tourism. However, employment analysis indicates that the most impacted sectors are industry, tourism and agriculture, respectively;
2. The study identified a number of policy options that can be undertaken and they are: Beach nourishment with hard structures and this option is already been done, Application of the Integrated Coastal Zone Management (ICZM), and Land use change either with change to less vulnerable lands or to another land use such as aquaculture;
3. It is important to establish an appropriate monitoring system to ensure compliance to regulations and implementation of adaptation measures.

In any adaptation plan, a survey of baseline adaptation policies, measures, environmental conditions, available technical tools and past experience is necessary to ensure suitability of the adaptation measure to be taken. It was suggested that a strategic environmental impact assessment must be carried out for any policy of adaptation and an environmental impact assessment of any measure. A survey of existing policy and measures, taken by various authorities, was carried out. An assessment of measures taken, based on the above mentioned attributes were judged by a multidisciplinary team.

A set of adaptation measures involves the management of low-lying lands on the northern fringe of the Delta, where the consequences of sea-level rise (submergence and salinisation) are likely to cause serious damage. Some of those lands cannot be used for agriculture, and the limited amount of water made available consequently should be delivered to the irrigation of new cultivated lands outside the New Valley and Delta.

2.5.5 Experiences and lessons learned

The lessons learned from the assessment are:

1. The importance of maximising the role of the national institutions. National monitoring programs and networks for collection and analysis of coastal indicators necessary for vulnerability assessment are needed. A network of decentralised geographic data bases based on remote sensing and ground based monitoring should be developed and updated regularly. All these activities require strong institutions;
2. Capacity has been built amongst the research team members involved in the project because many activities have been carried out. Field surveys, workshops, multi-

disciplinary research team meetings (scoring, discussions with different stakeholders, etc.) all these lead to scientific capacity building. Also, the tools been used for the study implementation;
3. Sharing knowledge and information and raising awareness between different stakeholders is important for the scientific capacity building and the formulation and evaluation of adaptation options;
4. The complexity of issues in vulnerability and adaptation assessment calls for well coordinated multi-disciplinary research teams;
5. Methodologies used in studies need to be in line with policy needs. The issue of adaptation is very much politically sensitive. Hence, proposals for solutions to already existing problems and measures to increase the adaptive capacity must go through the appropriate governmental channels.

2.5.6 Follow-up research

A number of follow up activities have already been carried out. For instance Eid and EL-Marsafawy (2002) carried out a more detailed assessment of impacts on agriculture. They reported that the potential impact of climate change could lead to a decrease national production of many crops (ranging from -11% for rice to -28% for soybeans) by the year 2050 compared to their production under current conditions. The study included simulation of on-farm adaptation techniques such as the use of alternative crop varieties, optimization of the planting date, increasing water and/or nitrogen fertiliser use as well as modifying plant population density in the field. These on-farm techniques, which may imply low additional costs to the agricultural system, are compensated partially or fully by increased yields.

In this connection, it should be mentioned here that, El-Raey and Frihy carried out another study on climate change scenario development using MAGICC/SCENGEN in 1999.

The following follow up activities are still required:

- Carry out a complete quantitative assessment of the vulnerability of the coastal zones applying the seven steps IPCC methodology, and using the latest data, particularly that obtained by recent satellite images;
- Develop and implement national monitoring programs and networks for collection and analysis of coastal indicators necessary for vulnerability assessmen;
- Include socio-economic issues and link the agriculture and water sectors in future coastal zone vulnerability and adaptation assessments;
- Set-up and regularly update national databases with all available data for and from climate change studies;
- Establish a network of tide gauges in sensitive areas, using recent systems applying GPS and satellite technology, to provide simultaneous data on land subsidence, waves and sea levels, particularly in vulnerable sites;
- Implement and monitor integrated coastal zone management including all relevant systems and areas;
- Study possible regulatory incentives and legal options and/or institute set for tourism in the Egyptian back zones;

- Carry out capacity analysis and detailed vulnerability assessment for tourism in the Egyptian coast. Improved management of tourism is considered a high priority in view of the expected increase in pressures on some specific coastal sites;
- Survey and evaluate existing and planned policy and measures taken by various coastal authorities. This assessment should be based on net benefit, effectiveness, costs, first and higher order impacts, fairness to stakeholders, etc. The coastal protection authority in Egypt has published many of these measures, and publications could be collected and analysed.

Although policy makers perceive adaptation to climate change as an important issue they do not have funds to support research in this area because of other pressing problems in the country. Hence, follow-up research in this area depends on donor funding.

2.5.7 Policy implications

The present study (El-Raey and Frihy, 1999) has been included in the national action plan (EEAA, 1995) and the Initial National Communication (EEAA, 1999) to the UNFCCC. Both are supporting attention for adaptation to climate change in the coastal, agriculture and water resources sectors.

Actual policy implications are:

1. **Beach nourishment and groins**: Beach nourishment strategies include depositing sand onto the open beach and beach scraping, building artificial dunes as storm buffers and beach sand reservoirs, and laying pipes underneath the beach to suck in the water and trap sand. Groins trap sand, which cover the beach.
2. **Breakwaters**: Breakwaters are hard structures used to reduce the wave energy reaching the shoreline. The net benefit of this strategy is only along the coastline. It is the best available tool the lowland areas protection.
3. **Application of Integrated Coastal Zone Management (ICZM)**. For the Red Sea area as an example, the plan is structured around distinct components, including integrated coastal marine planning requirements and approaches, sustainable tourism, risk assessment and management, information management, environmental awareness and preliminary zoning proposals.
4. **Land use change**: either with change to less vulnerable lands or to another land use such as aquaculture.
5. **Legal Development Regulation**: taking legal or regulatory actions to restrict development or prohibit development in a hazard-prone area. In Egypt, the regulation is effective only private companies.

2.5.8 Conclusions

Sea level rise could have major impacts on coastal systems in Egypt (Sestini, 1992; Delft Hydraulics,1992; El-Raey et al, 1995). The study indicates that, without serious adaptation measures, millions of people could be at risk of loosing their homes. Even with the 0.5 m SLR scenario the potential damage to the beaches and installations, and the loss of productive land are analyzed to have serious implications on job opportunities, food availability and population movement.

Main Products

EEAA (1995). *Report on Framework of National Action Plan for Dealing with Climate Change*, U.S. Country Studies Program.

EEAA (1999). *The Arab Republic of Egypt: Initial National Communication on Climate Change*, Prepared for the United Framework Convention on Climate Change UNFCCC.

Eid, H. M. (1994). Impact of climate change on simulated wheat and maize yields in Egypt. In C.Rosenzweig & Iglesias (eds). *Implications of Climate Change for International Agriculture: Crop Modelling Study*. Washington: US Environmental Protection Agency.

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Delft Hydraulics. (1992). *Implications of relative sea level rise on the development of the lower Nile delta, Preliminary assessment of socio-economic impacts and impacts on northern wetlands and fisheries. Egypt*. Pilot study for a quantitative approach.

2.6 Ghana

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2.6.1 Introduction

Ghana signed the United Nations Framework Convention on Climate Change (UNFCCC) in June 1992 and ratified it in September 1995. The UNFCCC recognises climate change as a major threat to the world's environment and development aspirations. Ghana being a tropical and coast lying country and heavily dependent on agriculture, for both export and domestic use, the potential impacts of climate change such as sea level rise, and change in local climate conditions (such as temperature and precipitation) could have important and significant negative impacts on the costal zone, food production, availability of biomass, hydro-energy sources as well as the level of biodiversity could be affected. Climate change could also significantly, affect sources of water supply, human health and terrestrial and aquatic ecosystems in the country.

UNFCCC commits the world at large to deal with the problem of climate change by limiting the emission of greenhouse gases and address themselves to adaptation should there be climate change. As a Party to the Convention, Ghana is required under Article 4 paragraph 1 and Article 12 of the Convention to prepare 'National Communication', includ-

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ing the inventories of greenhouse gas emissions and their removal by sinks, as well as information on policies and measures taken to adapt to the impacts of, or mitigate climate change.

Under the NCCSAP phase 1, Ghana carried out two important vulnerability and adaptation assessment studies in the areas of water resources and coastal zones. Two separate reports on water resources and coastal zone vulnerability to climate change have been published. Major highlights from these reports were captured in Ghana's initial national communication. The vulnerability of agriculture to climate change was addressed under the UNDP/GEF enabling activities. This paper addresses the water resources vulnerability assessment study.

Water resources are needed for domestic and industrial water use, sanitation, irrigation of crops, generation of hydropower, navigation etc. Hence, they are essential for socio-economic developments.

The rapid increase in the country's population will add to the current pressures on the quantity and quality of water. In general, climate change may put further constraints on the water resources because of changes in spatial and temporal distribution of the resources. The study therefore considered the potential impacts of climate change on flow characteristics of streams and rivers, irrigation water demand, hydropower generation, groundwater recharge, frequency and intensity of floods. In addition the socio-economic impacts of climate on water resources were assessed.

2.6.2 Approach

A representative basin approach was used because the entire river systems in the country could not be assessed due to limited resources. Three basins (Figure 1) were selected and they represent the Coastal, the South-Western and the Volta basin systems. The assessment was on the impacts of climate change on river discharge, floods, groundwater recharge, domestic and industrial water demand, irrigation water demand, hydropower generation and livelihoods (socio-economic). Teams of experts were constituted as working group to assess each of these study areas.

Synthetic scenarios of climate change were developed for temperature and rainfall. The scenarios were obtained from the base data by uniformly increasing or decreasing the magnitudes of the two hydrometeorological parameters. Scenario runs were carried out with the hydrological/water balance model (WATBAL) to test the sensitivity of the water resources to climate change. General Circulation Models (GCMs) and Regional Atmospheric models, which had been based on scientific principles, were used in deriving the most probable climate change scenarios. The hydrological model was then run with these GCM-based climate change scenarios.

Different time horizons for the climate change analyses were selected. The period of 1961 to 1990 was selected as the base period, while impact and vulnerability assessments were carried out for the periods 1991 to 2020 and 2021 to 2050.

Again the WATBAL model was used to assess the impact of climate change on stream flows. The model was calibrated and then validated over different time periods of the rainfall and temperature data. The calibration of the model was facilitated by the prior analysis of the historical data sets. The impacts on runoffs were assessed by comparing the simulated runoffs of the future climate change scenarios and the base climatic scenario.

Impacts of climate change on groundwater resources were assessed on the basis of groundwater recharge. The outputs from the hydrologic modelling were used in a water balance analysis to compute the changes in recharge under the climate change scenarios. The impacts of climate change on the following water resource systems: irrigation, water supply for domestic and industrial use and hydropower generation were carried out using the results of the hydrologic modelling in a water resource system model, Water Evaluation and Planning System (WEAP)

The CROPWAT model, which models water requirements for crop growth, was used to compute the potential crop water requirements and thus irrigation water demand. The results were used as input for the WEAP model for the various time horizons up to year 2050 in order to assess irrigation water demand.

The incidence of floods under climate change could not be assessed by any of the models because of the monthly average data used in the studies. Thus a literature study was carried out to find the state of art for assessing the potential of flood hazard under climate change. Empirical approaches were attempted in this direction.

Although vulnerability can be associated with any of the following four factors; annual availability, inter temporal distribution, water quality, and water requirement, most studies have measured vulnerability on the basis of annual water quantity (Kulshreshtha, 1993). Vulnerability is often expressed in one of the following alternative ways: water dependency, water resources constraints, water deficit, demand-supply balance and joint availability and use level criterion. In this study, the joint demand and supply level (JDSL) criterion described in Kulshreshtha (1993) were used. The JDSL criterion is based on both the available supply on a per capita basis and its relative utilization. The latter is defined as the demand-supply ratio. After evaluating the vulnerability of the country's water resources to climate change, there was the need to evaluate adaptation measures, which should be put in place to reduce the vulnerability. The adaptation options were assessed based on the approach given in Feenstra *et al.* (1998) and classification and adaptation strategies development were assessed using the approach given by Carter *et al*. (1994).

2.6.3 Results of the water resources vulnerability study

The results of the climate change impacts on water resources are discussed in more detail in terms of river discharge, groundwater recharge, irrigation, hydropower generation and socio-economic conditions, in the ensuing paragraphs. Box 2.3 gives a summary of the study results. Impacts of climate change in the areas of floods and domestic and industrial water demand were not assessed in detail. They are discussed shortly below.

Floods are usually associated with rainfall intensities with short duration of order of few hours or days. The GCM output and climate change scenarios developed only presented monthly average rainfall data. Relationships between historic 24-hr maximum rainfalls and monthly rainfall totals were investigated, but were inconsistent. Hence, impacts on floods could not be assessed. However, available literature (Dankwa, 1974; Mott Mac Donald, 1991; Opoku-Ankomah, 1996; Opoku-Ankomah. and Amisigo, 1998) indicated that in parts of the country devastating rainfall events and a relatively high number of 24-hour maximum rainfall events occurred in the last decade (1986-1995). Climate change scenarios also indicate an increase in temperature in all basins studied. An increase in air temperature and resulting evapotranspiration, is known to result in larger thunderstorms and a greater risk from flash flooding (Opoku-Ankomah, Y. and Amisigo B.A, 1998). When assuming climate change is already occurring today, this could indicate that the observed increases in flood frequency in recent times may not be merely a natural variability as stated in literature. Further studies will be needed in this area.

Domestic water demand is driven, to the large extent, by the population growth and socio-economic development (including industrial development). The direct impact of climate change, in terms of temperature and precipitation changes, on water demand by most industries is envisaged to be very small (i.e. mainly on cooling processes). This was not assessed in more detail. Due to lack of data, the impacts of climate change on domestic water demand could also not be assessed.

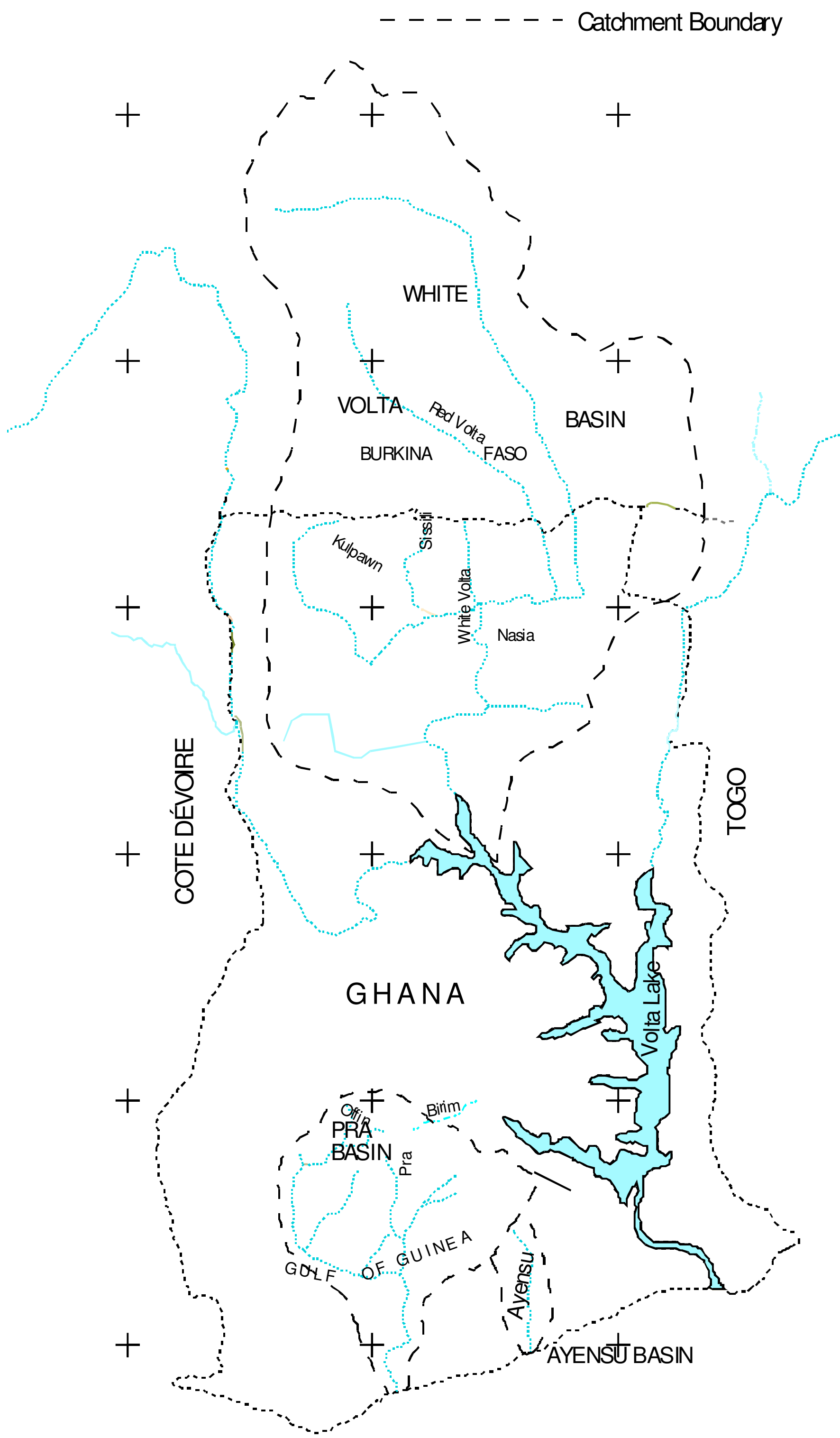

Figure 2.8 Representative Basins.

Box 2.3 Summary of general findings of the study.

1. There was observed increase in temperatures of about 1°C over a 30 year period and reductions in rainfall and runoff in the historical data sets;
2. Runoffs or discharges in all the representative basins are sensitive to changes in precipitation and temperature and thus to climate change. A 10% changes in precipitation or a 1°C rise in temperature could cause a reduction in runoff of not less 10%;
3. Simulations using climate change scenarios indicated reduction in flows between 15-20% and 30-40% for the year 2020 and 2050 respectively;
4. The last decade (1986-95) had most devastating rainfall events and relatively high number of 24-hour maximum rainfall events. Increases in historical temperature data set and evapotranspiration tend to support the occurrence of this physical phenomenon. A historical analogue may point to increases in flood frequency under climate change;
5. Climate change could cause reduction in groundwater recharge between 5 and 22% by the year 2020. Reductions for the year 2050 are projected to be between 30 and 40%;
6. Domestic and industrial water demand may not be affected by climate change but this needs further assessment;
7. Irrigation water demand could be affected considerably by climate change. In the humid part of the country, the increase in irrigation water demand due to climate change by 2020 and 2050 are about 40 and 150% of the base period water demand. For the dry interior savannah, the corresponding increases in 2020 and 2050 are about 150 and 1200% respectively. Further modelling of crop water requirements, indicates that vegetables have higher sensitivities to climatic change than cereals;
8. Hydropower generation could seriously be affected by climate change. The projected reduction by 2020 is about 60% from the base value in the Pra basin modeled by WEAP;
9. From socio-economic point of view, there may be secondary impacts on health, nutrition and energy-based industrial activities etc. if proper adaptation options are not embarked upon;
10. A vulnerability index involving the application of water availability and use criterion indicated that the country had water surplus in the base year (1990), except in the coastal basin. The coastal basin had water management problems in the base year. By the year 2020 and beyond all the basins will be marginally vulnerable. That is, the country will face water management problems;
11. The use-availability ratios in the country are very small. The values are 2-10%, 5-31% in 2020 and 2050 respectively. Should this ratio increase to 40%, to meet food security and for export, the whole country will be vulnerable;
12. Adaptation options suggested were in general for water conservation and efficient use of water for projected reduction in water resources.

River Discharge

Impact assessment on stream flow, and thus the surface water resources, was carried out through model simulations using WATBAL. The results indicate that runoffs are sensitive to changes in precipitation and temperature in all the representative basins. The magnitudes of the changes, are approximately similar in all the basins, however, these changes were not uniform. A 10% change in precipitation at constant temperature produced between 10% to 25% changes in runoff depending on the magnitudes of precipitation and temperature at which the changes occurred. Similarly, for a 1°C rise in temperature, there was a reduction of about 10% to 23% in runoff.

Simulations using GCM-based scenarios indicated reductions in flows for the future. Reductions in flows for the year 2020 are 17%, 20% and 16% for Pra, Ayensu and the White Volta basins respectively compared to the base period 1961 to 1990. Similarly, for the year 2050, the reductions are 33%, 37% and 37% for the corresponding basins compared to the base period.

These impacts of climate change on stream flows could have serious consequences on the nation's socio-economic development if proper adaptation strategies are not put in place.

Computed vulnerability indices based on only available surface water resources and population indicated a condition of water scarcity (extreme vulnerability) for all the basins apart from the Volta basin for the period 2020. The White Volta basin indicated a water stress (vulnerable) situation. The period 2021-2050, however, showed water scarcity for all the basins.

Groundwater Recharge

Groundwater resources are the main sources of domestic water supply in villages and some small towns in Ghana. Thus recharge of groundwater from supply point of view is important. Impacts of potential climate change on groundwater recharge in the representative basins were evaluated from the subsurface and base flow components generated from the WATBAL model. The recharge was estimated as the sum of subsurface flow and base flow.

In the base period, the mean annual recharge for Pra, Ayensu and White Volta basins were estimated at 3.83, 0.13, and 3.78 km^3/year respectively. In terms of depth, the corresponding mean annual recharges were estimated at 0.456, 0.207 and 0.224mm/year. Thus the estimated recharges in the relatively dry Ayensu and White Volta basins are about half of those in the humid Pra basin.

There were reductions in recharges in all the representative basins for the climate change scenarios in the year 2020 and 2050. For the year 2020, the reductions are 17%, 5% and 22% for Pra, Ayensu and the White Volta basins compared to the base period, respectively. The reduction in the Ayensu basin was unduly low. The reductions for the year 2050 were even greater and are 29%, 36% and 40% for Pra, Ayensu and the White Volta basins compared to the base period, respectively.

Comparison of the reductions in recharges of the groundwater to reduction in average stream flows showed similar results. This implies that climate change will equally impact on average stream flow and groundwater resources.

Irrigation

Irrigation of crops in the country is traditionally on a low scale due to the country's dependence on rain fed agriculture. Irrigation of crops is, however, bound to increase as to feed the rapidly rising population.

In assessing the impacts of climate change on irrigation water demand, the CROPWAT model was employed to determine the net irrigation water requirements using the temperature and rainfall scenarios for the base period and for they years 2020 and 2050. The net irrigation water demand was converted to gross water demand by dividing by the local efficiency factor of 0.54.

The gross water demand in the representative basins were determined for the year 2020 based on the areas planned to be put under irrigation by Ghana Irrigation Development Authority (GIDA). These GIDA plans (Ghana Water and Sewage Corporation (GWSC), 1998a) did not consider climate change. For the year 2050, the areas to be irrigated were estimated based on population increase from 2020 to 2050. The water demand was computed without and with climate change as a factor.

The results in the Pra basin indicate that the water demand for the year 2020 would increase by 510% and 551% from the base period 1961 to 1990 without and with climate change respectively. Thus the change due to climate change alone was estimated at 41% of the base value (4,200,416m^3). Similarly, for the year 2050 in the Pra basin, the changes with respect to the base values are 771% and 922% without and with climate changes respectively. Thus the change due to climate change alone in 2050 is 151% of the base value

In a similarly analysis, water demand for the year 2020 and 2050 in the Ayensu basin for climate change alone are 141% and 652% respectively of the base value 48,128m^3.

The water demands in the White Volta basin for the year 2020 and 2050 for climate change alone are 278% and 1,206% respectively of the base value (6,056,400m^3).

It is interesting to note that the changes in area put under cultivation from the year 2020 to 2050 in all cases were slightly less than 50% while the changes in the water demand due to climate changes were about a factor 4. Furthermore, the results of the study showed Table 2.5 that vegetables have higher sensitivities to climatic change than cereals, for example, rice.

Table 2.5 Percent increases in crop water requirements with temperature sensitivity.

Basin	Crop	2020 (1.5°C)	2020 (2.5°C)	2050 (2.5°C)	2050 (4.5°C)
Pra	Rice	1.9	4.6	12.1	9
	Vegetables	2	10.6	27.1	14.6
Ayensu	Rice	2.1	0.1	3.1	9.1
	Vegetables	2.7	4.2	8.5	13.5
White Volta	Rice	10.9	1.6	6	10.7
	Vegetables	11.9	4.6	13.9	15.7

Hydropower Generation

Hydropower generation is determined by the head of water behind a dam on a river. The head is also related to the amount of water behind the dam. In assessing the impacts of climate change on hydropower generation, the WEAP model was used in routing the flows through the dams for hydropower generation. The WATBAL model was first used in simulating the flows under different climate change scenarios. The output was then expressed as hydrological fluctuations and used as input for the WEAP model.

The WEAP model was run for the Pra basin only. The inflows showed reduction of about 45%. The energy generated for the base case (1990) was about 108 and 160 GWh for Awisam and Hemang respectively. However, for the altered climate scenarios, the energy generated was about 41% of the base values, a 59% reduction for the year 2020.

Socio-Economic Conditions

Only second order climate change impacts on livelihoods (socio-economic conditions) due to changes in supply and demand of the water resource were analysed. The findings indicate that both surface and groundwater resources will decrease across the country in the year 2020 and 2050. Water demand will, in general, increase due to an increase in population and the need for improvement in socio-economic conditions. Moreover, as indicated above, climate change will increase irrigation water demand in the country.

Simulation of hydropower, which formed 77% of electric energy at the time of assessment, indicated considerable reduction in hydropower output of order of 59%. Further, the detailed vulnerability index, which was less pessimistic indicator showed marginal vulnerability for the year 2020 and 2050 (Table 2.6).

Table 2.6 Vulnerability Index (Persons/10^6 m^3 of water - surface water).

Basin	1990	2020	2050
Pra	442**	1229****	3141****
Ayensu	948***	3064****	7768****
White Volta	301**	927***	2468****
National	354**	1313****	2789****

*=Water surplus (not vulnerable); **=Marginally vulnerable (water management problems); ***=Vulnerable (water stress); ****=Extremely vulnerable (water scarcity)

From the foregoing, there could be impacts on health, nutrition, employment, energy-based industrial activities, etc. if proper adaptation options are not embarked upon. Consequently two categories of adaptation options were proposed to address water demand and supply side management

Adaptation options to be embarked upon from the supply point of view include:

- Inter basin water transfer, e.g. from the Volta basin to the Coastal basin;
- Changing location or height of water intake points using floating intake structures;
- Installing canal linings and using closing conduits instead of open channels in transporting water, to say, irrigation fields;
- Integration of separate reservoirs into an integrated system;
- Artificial recharge of groundwater to reduce evaporation;
- Building of reservoirs on rivers, which have run-of-the-river intake points;
- Good land use practices to discourage siltation of dams and thus maintain live storage for hydropower generation, domestic and industrial water supply, especially during dry seasons.

Adaptation from demand points of view include:

- Reduction in transmission loses of water to demand sites;
- Efficient domestic appliances;
- Dual supply system, potable and non-potable;

- Recycle domestic water for non-potable uses;
- Reduction in irrigation water use, e.g. night time irrigation, drainage reuse and use of water effluent;
- Introduce low water use crops;
- Introduce high value per water use crops;
- Change irrigation systems to drip, micro spray;
- Reduction in industrial water use through reuse of acceptable quality water, recycling and dry cleaning technologies;
- Efficient water use for energy generation, e.g. keeping reservoirs at lower head to reduce evaporation;
- Build additional reservoirs and hydropower station;
- Construct low head run of the river hydropower;
- Introduce more efficient hydropower turbines.

2.6.4 Experiences and lessons learned

It has been realised that though the independent sectoral vulnerability studies lead to in-depth information and important conclusions, our experience now shows that we could have achieved better results and comprehensive policy options development and above all, the country would have derived much more benefits, if various working groups for the vulnerability and adaptation studies had talked to each other during the period of assessment. This goes to buttress the point that integrated vulnerability and adaptation assessment approaches are more profitable to a country than any detailed independent sectoral studies.

The greatest challenge during the studies was the availability of relevant data, especially for domestic and industrial water demand. The combined demand-supply criterion considers water use explicitly and the low ratio of water use to supply in the country gives it a less pessimistic picture.

2.6.5 Follow-up research

The following follow-up studies are proposed:

- There are strong seasonal variation in rainfall and runoff in the country; however, WATBAL model did not have seasonal parameters to take that into consideration. The hydrological modelling with seasonality aspect will be relevant to undertake. Impact assessments based on seasonal values will give a better picture of vulnerability in the basins;
- Changes in inter-annual variabilities of rainfalls and runoffs under climate change could pose a more serious threat to human survival than changes in the long-term means. This aspect of the study will need consideration;
- Climate change, climate variability and land-use can jointly impact on water resources. There will be the need to model these factors in our tropical environment;
- On the recharge studies, a direct modelling approach will be needed for more accurate results. There will be the need to measure some field parameters for the modelling;
- Further investigation will need to be undertaken to assess the impact of climate change in high intensity rainfall events and flood frequency;

- In this study, it was assumed that the impact of climate change on domestic and industrial water demands are very small. Existing scanty literature on the issue indicates a relationship between rainfall and domestic water demand. This will need to be investigated;
- Further work will be needed to estimate irrigation water demand for crop production to meet food security under climate change;
- There will be the need to undertake river basin management using WEAP in an integrated manner to resolve potential conflicts. The Volta basin should be studied in an international context. Conflict between irrigation development and hydropower generation and other uses will be examined.

Furthermore, a regional programme to follow-up on the outcomes of these studies for the management of the Volta basin should be implemented.

The follow-up activities have been presented to the Global Environment Facility and NCCSAP phase 2 for funding. In the NCCSAP phase 2 we anticipate to assess the cumulative impact of climate change and climate variability and land-use on water resources.

2.6.6 Policy implications

The methodologies and studies were in line with policy needs, consequently a number of policy initiatives have being implemented that either fully or partially responds to the outcomes of the studies.

As a result of the reduced power output from the Akosombo dam the Government of Ghana is now actively encouraging investors who wish to establish electric power generation, to invest in renewables, especially wind and solar power. Various projects are underway for the construction of solar powered generation. Others projects considered are a pilot project on the construction of wind-powered generators. In this project the feasibility of wind energy in Ghana should be determined before wider scale implementation.

The Government has restructured the power sector with the view of improving the supply situation and introducing competition into the power generation sector by encouraging independent power producers. This is to ensure better efficiency in the power sector.

Several years of reduced hydropower supply due to reduced inflows and increasing energy demand due to increasing population and economic activities, have led to a number of demand side management problems Ghana has constructed two thermal plants, which deliver a total of 300 MW of power.

Capacitor banks in high-energy consuming industries have been installed in order to correct power factors to reduce losses in the power system. Nation-wide campaigns have been undertaken in order to educate the public on ways of reducing their energy consumption. This was done by publicity through newspapers, radio and television advertisements and announcements. Seminars were also organised countrywide to educate the public on the hydropower generation situation and to urge them to use electric power judiciously. The Energy Foundation has developed a chart on relative power consumption of power appliances and has been prepared and published and energy efficiency standards and labels. This is to enable the general public to be aware of which of their appliances consume more energy so that they can manage their consumption better. Additionally, Ghana has constructed two thermal plants, which deliver a total of 300 MW of power.

The Volta River Authority, currently the only hydropower generator, imported power and is promoting the sale of compact fluorescent lamps (CFL), which have a higher efficiency than ordinary incandescent bulbs. The sales are being promoted through advertisements in the newspapers, radio and television. To encourage the use of the CFLs, Government has removed all taxes (including import duty and value added tax – 35% reduction of wholesale price).

The concept of demand side management is important, there is the need to install or build very efficient infrastructure capable of maintaining the right water pressures and water heads. In cases where there may not be adequate sources of surface waters, the infrastructure should either be improved to handle excess water from inter-basin transfers or supplemented with groundwater resources. There should also be proper conservation of waters during the wet season for usage in the dry season due to the spatial and temporal nature of the rainfall pattern in Ghana.

To promote efficient use of water Ghana Water Company has been allowed to charge economic rates to sustain its systems and also to serve as a deterrent to consumers on water wastage.

Additionally, there has been massive public education of farming activities along riverbanks. Government as well as the civil society have embarked on reforestation projects along the banks of some rivers.

Currently the Government is considering the promotion of rain harvesting in the northern section of the country to ensure that water is made available for farming and other uses. The major challenge of the entire studies has been how to integrate and mainstream the outcome of these studies into the national development agenda (i.e. the Ghana Poverty Reduction Strategy -GPRS)). As part of the ongoing strategic environmental assessment by the Environmental Protection Agency on the GPRS, a window of opportunity has been created that allows for the mainstreaming climate change concerns including adaptation into the GPRS. Full integration of climate change adaptation is, however, not envisaged until a national adaptation plan of action has been developed. It is the Government's plan to develop the adaptation plan of action as part of the NCCSAP phase 2.

The focus of future activities should be to formulate climate change policies that are consistent with the national poverty reduction strategy, and thus facilitating the mainstreaming of these policies into district as well national development plans.

This could be achieved through the:

1. Identification, (through investigations) of the biophysical and socio-cultural-economic environments, a range of methods by which Ghana may improve its capacity to respond effectively, efficiently and sustain ably to future climate change;
2. Incorporation of experience gained from the critical examination of present climate-related problems in the design of appropriate responses to anticipated climate change;
3. Identification of transferable models of good practice in response to present climate-related hazards;

4. Involvement of a wide range of stakeholders from governmental institutions and civil society in these investigations, in the knowledge that appropriate responses will involve the whole of society;
5. Examination of the plight of the most vulnerable members of society in relation to climate-related threats, with particular reference to livelihood strategies;
6. Raising of awareness of the threat of climate change among policy-makers, the private sector and civil society.

2.6.7 Conclusions

The results from the water resources studies have proven to be invaluable as they do give clear indication that the adverse impacts of climate change on Ghana's water is real. A country that once depended solely on hydropower now has to resort to thermal generation to meeting increasing demand.

The studies have revealed that the impact of climate change on water resources has a number of consequences – outlined above - on the well being of the people of Ghana, and efforts by Government have been taken to address these impacts. However, the major challenge that faces the country is the effective implementation of the recommendations from the studies. It has become increasing apparent that there is the need to develop a comprehensive policy for climate change adaptation that addresses also issues of land-management, vulnerability of the poor with particular emphasis on gender. Therefore the focus of future programmes in the area of adaptation, including work on water resource assessment, should be on the examination of the linkages between poverty and climate change and the consequences of climate change on the livelihood systems of poor communities.

Water dependency criterion indicated water scarcity or extreme vulnerability situation on the other hand. This method is less detailed and the former may be considered more appropriate.

Hydropower generation could be judged to be extremely vulnerable by 2020 due to over-dependence on this cheap source of electricity in the country. The reduction in power generation of order of 50% simulated for the Pra basin in 2020 underlines the fact that existing supply cannot meet future demand. Again, following form the results of the study it was recognised that the education of the general public on the economic use of water is important.

It was also learned that there is the need for diversification of crops by shifting to more drought resistant ones that require less water. Other measures include the improvement in irrigation techniques and practices through the adopting of those that use water more efficiently, e.g. unlined canal should be lined to prevent seepage and open main canal will have to give way to pipes. Moreover, efficient irrigation methods like drip irrigation should be preferred to less efficient ones like flooding and furrow and mulching and other water conservation methods will have to be applied in the fields. Finally, storage capacity (reservoirs) for irrigation must be increased wherever possible instead of allowing rivers and streams to flow into the sea unused.

Main products

Initial National Communication of Ghana (2001). Available from http://unfccc.int, 172 pp.

Opoku-Ankomah, Y. & Forson, M.A. (1998). Assessing surface water resources of the South-Western and Coastal basin systems of Ghana. *Hydrol. Sc. J.* 43, 733-740.

Opoku-Ankomah, Y. & Amisigo, B.A. (1998). *Rainfall and runoff variability in the south-western river system of Ghana. Water Resources Variability in Africa during the XXth Century*. Proceedings of the Abidjan'98 Conference, Cote d'Ivoire, November, 1998. IAHS Publ. No. 252, 1998.

Opoku-Ankomah, Y. (1998). *Volta Basin System Surface Water Resources in Water Resources Management Study. Information Building Block. Part II, Vol. 2*. Ministry of Works and Housing. Accra. Ghana.

2.7 Kazakhstan

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2.7.1 Introduction

Kazakhstan is situated in the central part of the Eurasian continent and has a dry continental climate. Preliminary impact and adaptation studies have shown that the natural resources and the economy of Kazakhstan are vulnerable to climate change. The Government of Kazakhstan supports climate change research activities including scientific research as a background of environmental protection policy actions and climate change strategy development for the future.

After signing and ratification of the UNFCCC, Kazakhstan started conducting climate change study projects and related activities under support of the U.S. Country Studies Program in 1995. During this project the first greenhouse gas inventory, vulnerability and adaptation assessments and mitigation analysis were carried out. Due to the large territory of the country, the diversity of climate conditions and the large variety of economic activities, it was not possible to cover all vulnerable sectors and regions in one study. It was required to focus the climate studies on the regions which are very important for the economic development of Kazakhstan. The densely populated foothills and mountain regions in the south-eastern part of the country and the oil and gas-extracting regions in the Caspian Sea coastal zone urgently needed a new strategy of prevention measures against mudflows and snow avalanches.

Climate change is expected to increase the risk of mudflows and snow avalanches pressing the need for a vulnerability and adaptation study. Furthermore, the Initial National Communication of Kazakhstan to the UNFCCC had not been prepared yet and a greenhouse gas inventory was required in accordance with the revised international methodology. The NCCSAP activities contributed to the continuation of these studies.

This section of the Country Chapter describes the results of the climate change impact, vulnerability and adaptation studies for Kazakhstan's part of the Caspian Sea coastal zone, as well as snow avalanches and mudflows in the mountains of Southeast Kazakhstan. The reason for selecting these studies to be presented in this section in more detail

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is that there were only a few publications on their scientific results in Kazakhstan or abroad. This book gives us an opportunity to distribute the results of these investigations.

The goals of the study were:

- To develop baseline and climate change scenarios for the studied regions;
- To conduct vulnerability and adaptation assessments of the Caspian Sea coastal zone and mountain and foothill areas under possible climate change;
- To prepare the recommendations to the Government of Kazakhstan in order to protect its coastal zone and for preventing a possible damage induced by mudflows and snow avalanches;
- To conduct cost evaluation of adaptation measures;
- To prepare recommendations to the Government for possible adaptation measures.

2.7.2 Approach

The approach of the study was based on the IPCC methods of assessing the impacts from and potential adaptation to climate change (Carter et al., 1994). This approach follows a seven step strategy according to IPCC Technical guidelines for climate impact and adaptation assessment (see also Section 1.5):

1. Definition of the problem;
2. Selection of the method;
3. Test of the method;
4. Selection of scenarios;
5. Assessment of impacts;
6. Assessment of autonomous adjustments; and
7. Evaluation of appropriate adaptation strategies.

This approach allows taking into account different scenarios, scales (global, local), and long term or short term effects. The retrospective analysis of mudflow activity during the Pleistocene provides a scientific background for the scenarios of change of mudflow activity in the course of global climate warming in the 21st century. The study of avalanche activity was based on the data of observations and climate change scenarios prepared for the region of the study. The Kazakh Research Institute for Environment Monitoring and Climate (KazNIIMOSK) has developed a water balance model for the calculation of sea water levels. The model allows determination of the sea level on the basis of river water inflow, water consumption changes in the basin, evaporation, precipitation and seawater runoff to the Kara Bogaz Gol gulf. Furthermore, a hydrodynamic model for simulation of storm surges developed by the Danish Hydrological Institute (Module MIKE 21) was adapted to the Caspian Sea conditions.

2.7.3 Results of the vulnerability assessment

In this paragraph the results of the vulnerability to climate change impacts and adaptation options for Kazakhstan's part of the Caspian Sea Coastal Sector and mountain region of South and Southeast Kazakhstan are described.

Climate Change scenarios

The Caspian Sea region

The general atmosphere circulation models were used to define potential changes in the values of temperature, precipitation and evaporation for the Caspian Sea area under climate change. The models predict a mean annual air temperature increase in the Caspian Sea area of 3.7-4.9°C, while the annual precipitation will increase by an average of 52 mm (the GFDL, CCC and UKMO models) or decrease by 4-8 mm (the GISS model). The effective evaporation (evaporation minus precipitation) may increase to 158-243 mm under the changed climate.

Southeast Kazakhstan

In accordance with the existing climate change scenarios in Southeast Kazakhstan in the coming 25-30 years the climate change can lead to increase of air temperature by 2-3°C (Assessment of impact and adaptation, 2000). To assess the effects of climate change a number of climate change scenarios were constructed. Currently, no reliable prediction can be made for regional climate changes, especially in mountainous regions (IPCC, 1996). Only more or less plausible estimations are available, based on GCM outputs and observed tendencies of the current climate. For the mountain regions of SE-Kazakhstan all general circulation models (GCMs) suggest an increases in annual temperatures ranging from 3.7 to 7.1°C under the assumptions of doubling CO_2 concentration, which is expected to occur between 2050 and 2075. In addition, we used incremental scenarios and some statistical relationships between climate characteristics and snow avalanche activity.

The Caspian Sea

Impacts

At present the Caspian Sea is a closed reservoir, its surface is almost 27 meters below the World Ocean level. Results of calculations of changes in runoff and effective evaporation in the Caspian Sea basin under climate change were used for modelling changes of the sea level for the first half of the 21st century. According to the data of the Russian State Hydrological Institute (SHI), the water consumption in the Caspian Sea basin reached 40 km^3 per annum by the end of the nineteen eighties. In the mid nineties the water consumption decreased to 30 km^3 per annum as a result of the general decrease in economic activity. According to SHI this level of water consumption will be maintained till the year 2000, after which a gradual increase will take place to 40 km3 per annum in the year 2020, the same level as in the eighties.

The results of the different models show that climate change in combination with an annual water consumption of 40 km^3 may cause the Caspian Sea level to rise 4.7 m with an 0.1% frequency (once a millennium) according to the CCC model, of 6.4 m according to the UKMO model, and of 1.0 m according to the GFDL model. Minimum runoff values were obtained using the GFDL model, while the UKMO model gave maximum runoff values.

It was calculated that the level of the Caspian Sea may increase to 5 m relative to its present value (minus 27 m) as a result of climate change in the middle of the 21st century. In this conditions the probability of the Caspian Sea level rising up to the minus 25 m level taking into account the forecasted water consumption in the Caspian Sea basin will gradually increase. This process will increase the probability of a catastrophic flooding of the Caspian Sea coastal zone in the Pricaspian countries in the middle of the next century.

The expected Caspian Sea level rise in combination with storm surges (or wind set-up) will cause high sea water levels. An evaluation of this effect was conducted using a hydrodynamic model for simulation of storm surges, namely the Danish Module MIKE 21 adapted to the Caspian Sea conditions by KazNIIMOSK. This simulation permitted to allocate specific surge heights to various zones along the Caspian Sea, and to evaluate the subsequent coastal flooding for three values of the background sea level: minus 27.0 m, minus 25.0 m and minus 22.0 m. It was found that the duration, height and intensity of the wind set-up will be increased by 18-20% by the Caspian Sea level rise.

Moreover during heavy storm surges the coastal zone will be flooded over a width of 30-50 kilometres, because of the low level of the Pricaspian Lowland. The eastern coast of the Northern Caspian including the Lower Emba River is the most vulnerable zone. The wind set-up height in this region will increase to 3 m and the seawater will penetrate into the coastal zone over a distance of 50 km. This catastrophic flooding of considerable areas will also lead to the leaching of large amounts of the polluting substances into the Caspian Sea.

The expected sea level rise will cause an increase of the groundwater level in the coastal zones. This influence was evaluated by the Institute of Hydrogeology and Hydrophysics. Their assessment showed that an increase of the ground water level will take place in the coastal zone over a width of 5-10 km. The groundwater level will increase in general by 0.3-0.5 m; only near the coast line the increase will amount to 1-2 m, in a few places to 3-4 m.

The gradual increase of the Caspian Sea level since 1978 has brought considerable damage to the Kazakhstan's economic activities at the seashore. When the sea level reached the minus 27 m level the damage amounted to US $1.1 billion. Due to the expected climate change in the next century the sea level will increase to higher levels. According to the existing climate change models, if the carbon dioxide concentration in the atmosphere is doubled, the sea level may reach the minus 22 m level and higher by 2050. If the sea would attain the minus 26 m, minus 25 m and minus 22 m levels respectively, the damages would amount to US $2.8 billion, US $11.9 billion and US $14.2 billion. The existing protective structures are insufficient to prevent flooding of former safe areas, settlements and economically important facilities.

Adaptation measures

The strategy for the protection of the Kazakhstan's Caspian seashore include: construction of sea defences (dikes), relocation of settlements, protection of oil and gas exploration facilities and infrastructure, protection of agriculture and fishery resources, protection of utilities. Thus, the recommended general plan for protection of the coastal areas from flooding consists of a broad range of adaptation measures. Its basic approach is the construction of frontal and ring dikes whose length will be increased from 330 km to 1206 km. These dykes will protect industrial enterprises, main oil- and gas fields, 92 settlements, 270 thousands ha of agricultural lands, and transport and social infrastructure. Protection of the population and the economic infrastructure threatened by flooding in case of a sea level rise to minus 26 m is an absolute necessity. This first stage protection will necessitate enlarging the existing sea defences to a total length of 1,148 km.

Mudflows

A mudflow is a flow of water so heavily charged with earth and debris that the flowing mass is thick or viscous. At the origin sites of rainfall-caused mudflows the precipitation normally falls as hail and snow only 1-2 times a century the liquid precipitation falls with an intensity that is sufficient to trigger large mudflows, which are capable to reach a debris cone. The last activation of glacial-caused mudflows, caused by disastrous emptying of reservoirs of moraine-glacial complexes, has taken place in the latter half of the 20th century, i.e. about 100 years after the end of the Small Ice Age (1850).

Former investigations, for example of the northern mountain ranges of the Tien Shan (the Zailiysky and Kungey Alatau Mountains), revealed that the mudflow activity was almost equal to zero under the climate conditions of the Ice Ages and it peaked during the Riss-Wurm interglacial period (120-130 thousand years ago).

During interglacial periods mudflows transport sediments, which accumulate in the mountain valleys. These sediments were reworked to moraines by glaciers during glacial periods. The study of structure of debris cones of the rivers of the northern slope of the Zailiysky Alatau Mountains, where the towns Almaty, Kaskelen, Talgar and Issyk. (total number of the population is about 2 million people) are located, show that 90-95% of the volume of mudflow deposits are formed in the Quaternary period. The volume of debris cones is various: from 0.8 to 18 km^3, half of their volume consists of mudflow deposits of the Riss-Wurm interglacial period, when in the Antarctic Continent air temperature was 2.6 °C higher than present day (Stepanov and Yafyazova, 1995).

Designing and building of the main mudflow check-dams at the rivers of the northern slope of the Zailiysky Alatau Mountains were realised in the period 1960-1990, when the patterns of transport of sediments to the foothill plain (debris cones) were not discovered yet. Their discovery revealed a discordance between the existing capacities of mudflow-storage reservoirs and the necessary capacity. Due to potential climate change mudflow activity will increase tens to hundreds of times compared with the mudflow activity of the 20th century (Stepanov and Yafyazova, 2001, Yafyazova 2003). At present, the existing defense strategy against mudflows is based on detention of mudflows in the mountain valleys by means of dams. In the future this will not only be economically ineffective, but even dangerous. The overfilling mudflow-storage reservoirs may become the objects of increased mudflow hazard in case of dam failure. Figure 2.9 shows a mudflow in Zailiysky Alatau.

Figure 2.9 A frontal wave of the mudflow of 15 July 1973, enveloped in a mud cloud, entering the reservoir in the Medeo trough (the Tien Shan). Its discharge was 10000 m3/s; depth 15 m; velocity 10 m/s; and density 2380 kg/m^3.

Snow avalanches

In Glazovskaya and Troshkina (1998) possible changes of snow and avalanche characteristics, such as snow depth, number of days with intensive snowfalls (>10 cm/day) and the duration of the avalanche-hazardous period, were assessed for the mountains of the former Soviet Union under CO_2 doubling in the atmosphere. For the development of their climate change scenario they used GFDL model outputs. According to their results the snow depth in the mountains of Kazakhstan and Kyrgyzstan can possibly increase by 0 to 10 cm. At the same time the increase in the number of days with intensive snowfalls is expected to be 5 - 25%. The duration of the avalanche-hazardous period will be reduced by 10 - 20 days. In other words the winters will get shorter, but snowier. Crucial would be, however, to know the lower boundary (altitude) above which these trends shall take place. The results of Glazovskaya and Troshkina are aggregated for the areas considered. But they are not in contradiction with our results although we have not used the GFDL scenario, as it seems not to apply well for southeast Kazakhstan.

In the near future (10-20 years) no dramatic changes in the snow and avalanche conditions are to be expected in the mountain regions of Southeast Kazakhstan. However, as a result of the predicted temperature increase, the snowline is likely to rise and this means that the lower boundary of the avalanche risk zone will also rise.

Under doubling CO_2 conditions, which are expected to happen between 2050 and 2075, the snow line may rise by about 700 m. That means that the snow conditions of today at 2,300 masl (e.g. at the Shymbulak ski winter resort) will in future prevail at 3,000 masl (e.g. close to the Shymbulak snow avalanche station). In the upper part of the Shymbulak ski area only 180 days of snow coverage (instead of 240) can be expected and the annual maximum snow depth may be reduced to only 75 cm (instead of about 125 cm).

Especially in mid-winter (December - February) more snow and, consequently, also more avalanches can be expected down to low or at least medium altitudes. In spring (March/April) snowfall will increasingly turn into rain, with the effect that the snow cover at low to medium altitudes will melt earlier and only at high altitudes snow will remain.

Since in the long-term the lower boundary of the avalanche risk zone (today at about 1,500 masl) is likely to rise, low-lying infrastructures such as the Medeo skating rink (1,600 masl) or the Medeo - Shymbulak road may be less endangered or at least the period of potential avalanche hazard will be reduced. However, higher up in the mountains the avalanche hazard may even increase due to the possibly snowier conditions and remain a considerable risk, particularly for skiers and mountaineers.

2.7.4 Experiences and lessons learned

The conduction of impact and adaptation study the IPCC climate impact assessment methodology was used based on the seven steps method. The obtained results support the government in developing new strategies against mudflows and snow avalanches as well as for protecting the Caspian Sea coastal zone. Experiences to apply climate change scenarios and different physical models were gained. A lot of observational data on climate from meteorological stations and field observations and were used. Interesting results were obtained using multi-disciplinary approach due to expertise of specialists from different areas. A comprehensive analysis was carried out for The Caspian coastal zone including effects of storm surges and climate change impacts on underground waters. Policy makers are considering the proposed measures, which indicates that the study was relevant.

2.7.5 Follow-up research

Research on mudflows shows that the mudflow deposits of the Holocene (the last 12 thousand years) make only 1-2% of the total volume of mudflow deposits of the Riss-Wurm interglacial period, though in a climatic optimum of the Holocene air temperature exceeded the current air temperature by about 1 °C. This leads to the following question: why did the increase of air temperature by 1 °C in comparison to the air temperature of the 20th century not lead to a significant activation of mudflows? Unfortunately financial resources lacked to answer this question.

The snow avalanche study was followed by the introduction of a system to forecast snow avalanches, based on the Swiss model NXD2000. This may provide the avalanche forecaster with information about former days with similar condition and makes the forecasts more precise. The NXD2000 is in operation for forecasting snow avalanches in Zailiyskiy Alatay.

2.7.6 Policy implications

The studies described above have indicated a list of measures that would contribute to sustainable development of mountain and foothill regions of Kazakhstan as well as Kazakhstan part of the Caspian Sea coastal zone. However these measures will not be fully realised. The main reasons are the lack of sense of urgency by the officials (global climate warming will not happen in the near future), and the absence of legislation to regulate realization of adaptation strategies.

For activation of preventive measures against mudflows and snow avalanches it is necessary to introduce new concepts for defence strategies, the acknowledgement of the impacts of climate change by the Kazakh government, to develop performance requirements for preventive measures, and to create awareness about the relevance of preventive measures among the population.

2.7.7 Conclusions

The study performed under the NCCSAP was very important for the government and demonstrated the necessity of further actions to protect natural recourses, vulnerable regions and economy against climate change. New strategies were proposed which are very important even if climate change would not have the expected impact. The strategies are even useful for the current situation.

It should be noted that the conclusions about the possible increase of the Caspian Sea level during the first part of the 21st century are preliminary. Further studies are required. They should be aimed at the using of improved GCMs, and the assessment of runoff change of River Ural and other rivers on the Caspian Sea's western coast (Kura, Terek etc.). Furthermore, it is necessary to obtain precise data on the time of transition of the Caspian Sea level from current climate to the conditions of anthropogenic climate change caused by the CO_2 concentration doubling in the atmosphere. Also it is important to make a detailed assessment of the storm surges characteristics and ground water level increase in the coastal zone. All these studies will allow us to clarify the adaptation measures of the coastal zone to the possible disastrous sea level rise and to assess the required expenditures.

The study on formation of mudflows in the northern mountain ranges of the Tien Shan (the Zailiysky and Kungey Alatau Mountains) has shown that the climate is a main factor that defines the mudflow activity in this region. The research in the framework of NCCSAP was successful because of the integrated approach of the program: it included climate change - vulnerability - adaptation. As a result of limitation of financial resources the research of mudflows was limited to the development of evaluation methods of mudflow risk. The study of climate change influence on mudflow activity will allow optimisation of measures for damage reduction.

Climate change would, in principle, not limit the development of the Zailiysky Alatau as an important tourist and resort area. The main limiting factors rather lies in the legislative, social and cultural sphere. The development and implementation of defence measures against snow avalanches is very important for a further sustainable development of the region. And therefore the demand for accurate avalanche forecasts and avalanche warning will rise. Hence, one of the principal measures in developing a defence strategy against snow avalanches is the improvement of the observational system and the continuation of research on snow avalanches and other natural hazards. It is necessary to expand the area of snow cover and avalanche studies to the high mountain zone, and to neighbouring valleys of the Little Almatinka river basin, taking into account the perspectives of winter tourism development. The existing defence system is not sufficient to prevent damages from avalanches. Therefore adaptation strategies include both short- and long-term measures.

Main products

Assessment of impact and adaptation to climate change for Kazakhstan's Part of the Caspian Sea Coastal Sector and Mountain Region of South and Southeast Kazakhstan. Summary for policymakers (2000). KazNIIMOSK, Almaty, 51 p.

Stepanov, B.S. & Yafyazova, R.K. (1995). Features of formation of debris cones on the northern slope of the Zailiysky Alatau Mountains. *Hydrometeorology and Ecology,* 3, 18-28 (in Russian).

Stepanov, B.S. & Yafyazova, R.K. (2001). *Radical review of the defence strategy against mudflows is a necessary condition for the sustainable development of the mountain and piedmont regions of Kazakhstan. Problems of Hydrometeorology and Ecology*; Proceedings of the International Scientific and Practical Conference, Almaty, Kazakhstan, September 12-13, 2001: pp 32-35. (in Russian)

Yafyazova R.K., (2003). *Influence of climate change on mudflow activity on the northern slope of the Zailiysky Alatau Mountains, Kazakhstan.* Proceedings of the Third International Conference on Debris-Flow Hazards Mitigation: Mechanics, Prediction, and Assessment, September 10-12, 2003 Davos, Switzerland, pp. 199-204.

Glasovskaya T.G. and E.S. Troshkina (1998). Global climate change impact on the avalanche regime on the territory of the former Soviet Union. In: *Materials of glaciological studies*. Chronicle, Discussions. Moscow., Issue 84. pp 88-92. (in Russian)

2.8 Mali

Abdoulaye Bayoko[21]

2.8.1 Introduction

Mali is a Sahelian country situated in West Africa. Its economy is essentially based on agriculture and livestock farming which are both strongly dependent on the availability of water resources.

In the agricultural sector cotton is an important export product bringing hard revenues while maize is an important food crop for the entire population in the country. Livestock is the third largest export product of Mali after cotton and gold. Livestock based income was valued at US$ 287 million in 1998, equal to 9,28% of the gross domestic product (GDP). Exports of livestock during the same year were US$ 122 millions

Considering the importance of agriculture (i.e. maize and cotton production) and water resources to the national economy these sectors were selected for an assessment of climate change impacts, vulnerability and adaptation under the NCCSAP. The studies were based on earlier studies performed under the US Country Studies Programme amongst others, which were also implemented under the United Nations Framework Convention on Climate Change (UNFCCC) in Mali. The studies enabled the expert teams in Mali to improve methodologies used in the previous studies and refine results using more plausible climate and socio-economic scenarios for Mali (CNRST / Project Climate / study1, 2003).

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Two basins were selected for the assessment: the Baoulé to Bougouni and the Sankarani to Sélingué, which are indicated in Figure 2.10.

2.8.2 Approach

The studies were carried out using the basic climate change vulnerability and adaptation assessment approach described in Carter et al. (1994) and Feenstra et al. (1998).

First meteorological (rainfall, temperature, etc.), socio-economic activity and hydrological data were collected. To enable climate change scenario development, historical meteorological data were also collected for other locations in Mali. Additionally socio-economic data was collected for the country as a whole. Then climate change and socio-economic scenarios for the years 2000 (the base year), 2025, 2050, 2075 and 2100 were developed using the methodologies described in Feenstra et al. (1998), Carter et al. (1994) and Magic-Schengen (2000).

This was followed by an analysis of the hydrological parameters in the study areas (including amongst others ground water levels and the available water volumes etc.) for the base year and the identified future years. After assessing the water needs for the different socio-economic activities (agriculture, livestock, electricity production, and fishery, a comparison was made between the water supply (surface and ground water) and water demand for the socio-economic activities. This gave the supply-demand ratio and identifies the possible shortfalls in water supply for the two study areas.

The impacts of climate change on the water resources were assessed using the following models:

- RAINRU (Professor H. Savenije, IHE Institute of Deft Netherlands.) for the determination of runoff and the available water volumes in the basins according to rainfall;
- CRIWAR (Crop Irrigation Water Requirement), (International Institute for Land Research and Improvement, Wageningen, the Netherlands) for the determination of water needs by plants according to the meteorological conditions;and
- An empiric model (Doorenbos and Pruitt, 1986) to translate the impacts of deficits in water on the cereal yields.

The model results combined with scenarios of water demand for domestic and industrial use and for other socio-economic activities, gave the estimated socio-economic impacts of climate change in the two basins without adaptation. Based on these results and adaptation measures were identified for the two basins for different timeframes. Focus of the impact and adaptation assessment was on the base year and the year 2025. In the following paragraph some results for the base year and for the year 2025 are presented.

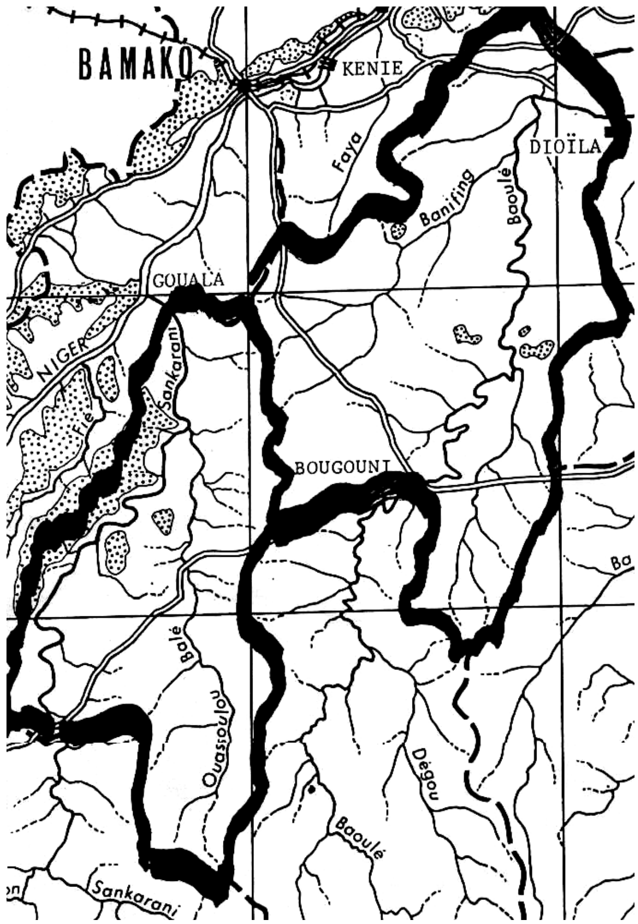

Figure 2.10 The area of the study includes the two basins of the Sankarani (left area) and of the Baoulé .

2.8.3 Results

Introduction

The renewable water resources come from infiltration of rain and surface water. These quantities have been estimated on the basis of the level fluctuations measured by the piezometer[22] network. In addition, relationships between rain, infiltration and depth of water tables were established.

The renewable water resources in the aquifer of the zone amount the order of eight billion m^3/year in periods with an average rainfall. The total water reserves include the recourses with recently infiltrated rainwater combined with the resources formed in the last millennium and before.

[22] A piezometer is nonpumping well, generally of small diameter, for measuring the elevation of a water table.

The baseline scenario

Table 2.7 to Table 2.12 show the estimated runoffs for the two basins investigated, with and without climate change. Table 2.9 and Table 2.12 show the estimated water resources available with and without climate change.

Table 2.7 Results of the estimations of the river runoffs by means of the RAINRU model for the period 2005 - 2025 in the Basin of Baoulé at Bougouni (m^3/s) for the baseline scenario.

	2005	2010	2015	2020	2025
January	0.90	0.90	0.90	0.90	0.90
February	0.90	0.90	0.90	0.90	0.90
March	0.90	0.90	0.90	0.04	0.90
April	0.90	0.90	0.90	0.90	0.90
May	0.90	0.90	0.90	0.90	0.90
June	15.22	17.44	19.59	21.74	23.89
July	87.80	93.68	99.38	105.07	110.77
August	182.69	192.79	202.57	212.34	222.12
September	230.59	242.74	254.50	266.25	278.01
October	184.87	194.02	202.88	211.73	220.59
November	100.27	105.46	110.48	115.50	120.52
December	26.54	28.04	29.49	30.93	32.38
Annual average	69.37	73.22	76.95	80.60	84.40

Table 2.8 Results of the estimations of the river runoffs by means of the RAINRU model for the period 2005 - 2025 in the Sankarani at Sélingué (m^3/s) for the baseline scenario.

	2005	2010	2015	2020	2025
January	7.62	7.62	7.62	7.62	7.62
February	7.62	7.62	7.62	7.62	7.62
March	7.62	7.62	7.62	0.05	7.62
April	7.62	7.62	7.62	7.62	7.62
May	21.37	21.81	22.25	22.69	23.13
June	111.20	113.99	116.77	119.54	122.33
July	308.16	314.24	320.28	326.32	332.40
August	563.89	572.93	581.94	590.96	600.01
September	785.28	796.88	808.47	820.06	831.67
October	715.20	725.98	736.77	747.54	758.33
November	328.70	334.71	340.73	346.74	352.76
December	53.69	55.21	56.73	58.25	59.78
Annual average	243.17	247.19	251.20	254.59	259.24

Table 2.9 Total available water resource in the two basins the period 2005 - 2025 in the baseline scenario.

Water resource in 10^9 m^3	2005	2010	2015	2020	2025
Renewable water resource	12.65	12.76	12.97	12.97	13.08
Available water resource in the two basins	9.86	10.10	10.35	10.57	10.84
Total of available water resource	22.51	22.86	23.32	23.54	23.92
Reserves	82.1	82.1	82.1	82.1	82.1

Table 2.10 Results of the estimations of the river runoffs by means of the RAINRU model for the period 2005 - 2025 in the Baoulé at Bougouni (m^3/s) for the climate change scenario.

	2005	2010	2015	2020	2025
January	0.98	0.98	0.98	0.98	0.98
February	0.98	0.98	0.98	0.98	0.98
March	0.98	0.98	0.98	0.05	0.98
April	0.98	0.98	0.98	0.98	0.98
May	0.98	0.98	0.98	0.98	0.98
June	4.18	3.27	2.55	1.27	0.98
July	62.69	60.49	58.24	55.84	49.38
August	147.11	144.67	142.12	139.50	128.92
September	189.86	188.46	185.52	183.76	171.40
October	156.85	156.56	154.78	154.21	145.31
November	84.38	84.82	83.89	83.96	80.13
December	21.49	21.74	21.37	21.46	20.56
Annual average	55.95	55.41	54.45	53.66	50.13

Table 2.11 Results of the estimations of the river runoffs by means of the RAINRU model for the period 2005 - 2025 in the Sankarani at Sélingué (m^3/s) for the climate change scenario.

	2005	2010	2015	2020	2025
January	7.62	7.62	7.62	7.62	7.62
February	7.62	7.62	7.62	7.62	7.62
March	7.62	7.62	7.62	0.05	7.62
April	7.62	7.62	7.62	7.62	7.62
May	17.89	17.59	17.24	16.89	15.44
June	88.88	86.80	84.76	82.23	72.82
July	258.87	253.88	249.74	243.47	222.38
August	493.86	487.42	481.50	474.12	444.93
September	708.70	705.05	700.17	696.29	668.77
October	647.86	650.25	645.29	645.26	630.43
November	290.16	298.43	290.81	293.05	287.41
December	45.09	50.38	46.32	47.92	45.71
Annual average	215.15	215.02	212.19	210.18	201.53

Table 2.12 Total available water resource in the two basins for the period 2005 - 2025 in the climate change scenario.

water resource 10^9 m^3	2005	2010	2015	2020	2025
Renewable water resource	12.22	12.21	12.15	12.13	11.65
Available water resource in the two basins	8.55	8.53	8.41	8.32	7.94
Total of available water resource	20.77	20.74	20.56	20.45	19.59
Reserves	82.1	82.1	82.1	82.1	82.1

Water needs

Table 2.13 shows that the accumulated water demand for the population, agriculture, livestock and other sectors is expected to increase from 1.20 billion m^3 in 2000 to 2,26 billion m^3 in 2025. The electricity sector has the highest demand and is expected to increase from 5.65 billion m^3 in 2000 to 6.47 billion m^3 in 2025.

So the total water volume used for the socio-economic activities is 6,85 billions of m3 in 2000 and will be 8,73 billions of m3 in 2025, either an increase of 127% on a period of 25 years.

Table 2.13 Water demand in 10^9 m^3 in the two basins.

Years	2000	2005	2010	2015	2020	2025
Population	0.007	0.008	0.009	0.011	0.012	0.014
Livestock	0.011	0.013	0.016	0.019	0.022	0.027
Agriculture	1.18	1.33	1.51	1.73	1.94	2.22
Other activities	1.198	1.351	1.535	1.76	1.974	2.261
Electricity production	5.69	6.18	5.30	5.59	5.30	6.47

It appears that the renewable water resources can cover the needs of the main socio-economic activities up to 2025, as can be concluded from Figure 2.11. However, the results of this global comparison can overlook the existence of local deficits during certain periods of the year. Hence, a more detailed analysis for the study areas needs to be carried out in the future. Estimated impacts without adaptation and adaptation measures in the different sectors are presented separately below.

The agricultural sector

A monthly analyse of crops water demand by means the using of the CRIWAR model (Projetclimat/CNRST/study1, 2003) showed that showed that, without adaptation, changes in monthly distributions of precipitation will have a negative impact on rain fed agricultural production. For maize this would lead to a decrease in production in the study areas, which is caused by a progressive reduction of the length of the rainy season. It would also entail a significant in cereal production in the study areas. A reduction in the length of the growing cycle of these crops was found in certain areas, such as in Bougouni. This is because of the temperature rise as foreseen by the climate change scenario (Projetclimat/CNRST/study1, 2003)

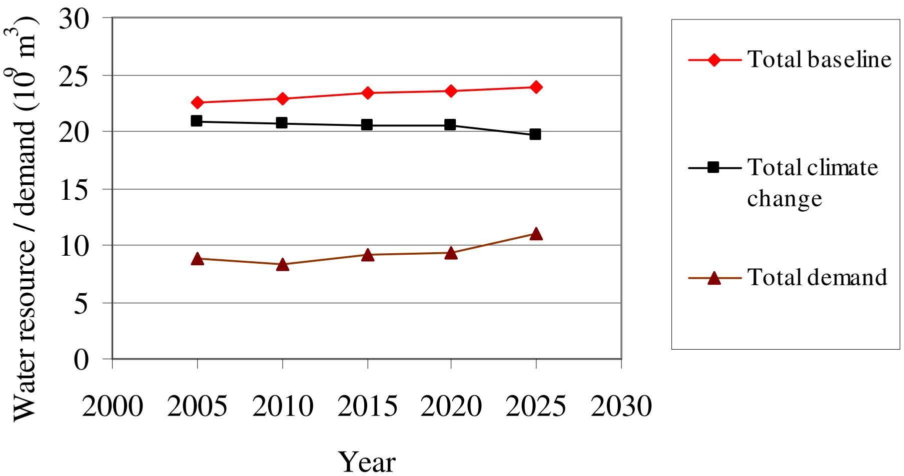

Figure 2.11 Comparison of water supply (for 2 scenarios, one without a climate change and one with a climate change) and water demand by the socio-economic sectors in the Basins of Sankarani and the Baoulé.

The production losses and economic losses to cotton producers in the different study areas without adaptation are presented in the table below. Table 2.14 shows the impact of climate change on the cotton production and the economic losses of this main industrial crop for Mali.

Table 2.14 Estimated cotton production and economic losses without adaptation in the study areas for 2005 and 2025 under the climate change and socio-economic scenarios.

	Production losses (tonnes)		Economic losses (1,000 US$)*	
Study area	2005	2025	2005	2025
Bougouni basin	150	450	51	153
Koutiala basin	200	1600	68	544
Dioila basin	1500	3500	510	1190
Yanfolila basin	370	750	126	255

* 1 US$ = 175 F CFA, 1 kg cotton valued at US$ 0.34 (2000 values)

The most realistic adaptation measures must be focused on the control and the management of water resources and the use of crop varieties that are less vulnerable towards climate change.

The natural sources of water for rural communities (the main part of the population) and livestock are surface water and groundwater. As these water resources are expected to decrease with climate change (Projetclimat/CNRST/study3, 2003), adaptation measures that were identified to meet the demand for water. These include irrigation, water storage, water import, construction of wells and pools, raise the awareness on good water management practices and improve livestock breeding practices. However, it is expected that financial resources of farmers are insufficient to pay for water transport and the realisation of wells. Moreover, it is likely that people will migrate to other areas in times of water shortage as this is common practice for the people of Mali, especially for communities depending on livestock. Under the climate change scenarios assessed water shortages could result in an exodus of people from the basins to urban centres and into neighbouring countries. Cattle will be also be affected because the river that they were using for drinking water will dry up. The best solution for this would be the construction of a reservoir and to fill it regularly with water.

Electricity production

Climate change could affect the electric energy production by hydropower facilities because at least 70% of the national energy production is hydroelectricity. In order to minimise the effects of climate change, appropriate measures should be taken in time to secure the levels of electric energy production by hydropower facilities. Possible measures to assure electricity supply and demand iclude:

- The modification of the management plan for inflow and outflow of the Sélingué reservoir;
- The creation of more works to retain water allowing a better flow regulation of the Sankarani river upstream of the Sélingué dam. This to avoid surpluses in water to flow away in the months September and October; and
- Thee reinforcement of the electricity production network by importing electricity, e.g. from the Manatali dam (which concern Mali, Senegal and Mauritania) or from other neighbour countries such as Ivory coast .

Fisheries

Fishery are bound directly to the abundance of water and therefore to rainfall. This is illustrated by the following example: the total fish captures in Mali is approximately 110.000 ton during an average year of rainfall, as for example in 1966. In a dry year the captures drop dramatically, as for example in 1984 when only 54.000 ton was caught, a decrease of nearly 50%.

The lake Sélingué dam has a maximum storage capacity of 2 billion m^3 of water. This makes the restocking of capital in piscatorial products possible. A reduction in precipitation in this basin in the period 2005 - 2100 as predicted by the climate scenarios used in this study, will reduce the area of flooded surfaces and thus the amount of fish.

The reduction of fish quality and quantity will push fishers to adopt others methods and tools for fishing. This might lead to an overexploitation of the resources and could lead to a change in the stock and a decrease in fish yield. As in the past during times of fish shortage, tensions can be expected to arise between communities because the arrival of news fishers by migration and the difference in the fishing methods by the different communities

2.8.4 Experiences and lessons learned

During the studies several lessons were learned. Below some of the experiences and lessons learned are presented for specific areas.

Data availability and models

The analysis of climate change impacts in the domain of water resources requires the use of models. These models require data that are not always readily available. Even when these data sets exist they are often either insufficient or limited to local circumstances.

As a result the study was performed with limited data sets for some areas. Because of the data limitations complex models could not be applied and therefore, the results had to be based on simple models. It is important to note that the national experts that carried out the studies were not used to some of the models, which had not been not available before locally. Hence, assistance was needed from international experts. They were not always available for missions, which led to delays in the implementation of the study. National experts were very committed to the project. For example, they participated in training sessions and spent more time on the project than they were obliged to.

Multidisciplinarity and interdepartmental project scope

Working in multidisciplinary and interdepartmental teams helped to overcome difficulties (such as human resource management difficulties, the needs of appropriate expertises) and promoted the exchange of knowledge and data between the different services (national technical services, private sector and NGOs) and the national team. Another merit of the multidisciplinary approach was that during the whole project, from developing scenarios until the analysis of the impacts of climate change on society, the experts in different fields worked together. This improved the insight on how climate change can influence water resources and how this will influence production (agriculture, livestock breeding, fishery etc.) and the population (food security, income, mobility, water bound conflicts).

2.8.5 Follow up research

Results of this project form a good basis for future, more in depth, assessments of climate change impacts on socio-economic systems in Mali. During different seminars several specialists expressed their interest in relation to the results of this project and considered initiating studies in other sectors, such as irrigated rice production and dairy production, including the quality of nutrition of milk and milk products. Research in the area of irrigated rice will need to be linked with research conducted in Niger, which has the potential to become one of the main irrigated rice suppliers in Africa. A study on the impacts of climate change on human health is now in progress together with experts from Burkina Faso.

2.8.6 Policy implications

The project contributed to raising awareness on climate change issues under political decision-makers. Especially the results of the climate change impacts on cereal production and how these changes negatively affect producer incomes were elements that grasped the attention.

Also the general public, confronted with the study results, saw their relevance and the necessity of taking adaptation measures to meliorate the impacts of climate change.

The political authorities appreciated the project results and desired that the different actors would take notice of the climate scenarios and the use of these scenarios for the development of the adaptation strategies. First actions in this regard were taken during the exploratory consultations for the identification of activities for the NCCSAP phase 2. All actors present were unanimously positive on the quality of the results of the first phase.

They agreed on the necessity to capitalise results of this phase in the second phase. To the first rank of these actors was the Chief of Staff (Vice Minister) of the Ministry of the Environment. This illustrates the interest of Malian authorities in climate change impacts and adaptation.

2.8.7 Conclusions

The use of simulation models requires a compilation of different data. Moreover, the quality of the model results depends on the quality of the data input. The lack of data for some locations influenced the choice of the study areas and the models that could be used. Hence, results should be seen as first order estimates.

Climate change impacts on water resources and agricultural production in the basins of Bougouni, Dioila, Yanfolila, Sélingué have been determined for different timeframes (2005 to 2025). Additionally a first order assessment of climate change impacts on hydro electricity production in the Sankarani basin, was made.

It is concluded that climate change will lead to a decrease in rainfall and an increase in temperature in Mali. The decreases in rainfall will lead to significant water shortages in specific areas. In areas with severe water shortages the local population and policy makers will have to take adaptation measures to cope with climate change. Local measures could include importing water, water and crop storage for the delayed use of water resources and stocks of foods, improved water resource management and digging wells. Costs of these activities can be expected to be a limiting factor. Hence, climate change can be expected to lead to large groups of people migrating to areas where water would be available, to the urban centres and to neighbouring countries if governments and other stakeholders do not take appropriate adaptation measures. Adaptation measures identified in this study include:

- The realisation of small scale dams, construction of reservoirs to retain water and the creation of other new systems to retain surface water;
- Measures to secure the income of the population. This will involve changes in agriculture, fisheries and market cultures. Policies to restrain the use of water resources and mobilise the people of Mali; and
- Policies to mobilise other partners, such as NGOs, the private sector and bilateral and multilateral partners) etc.

More in depth studies are needed to identify the most appropriate adaptation measures and strategies. The results of this project provide a good basis for these future studies. The government of Mali is highly interested in the issue of climate change and acknowledges the need for adaptation measures to be taken. Indeed, for a country as Mali, situated in arid and semi-arid zones in Africa, adaptation to climatic change is a question of survival and not of choice.

Main products

CNRST / Project Climate / study1 (2003). *Elaboration of climate change scenarios for Mali*, National Centre of Research and Technology, April 2003 Bamako Mali, 96p.

CNRST / Project Climate / study2, (2003). *Vulnerability and adaptation of the maize and the cotton at the climate change in Mali*, National Centre of Research and Technology, April 2003 Bamako Mali, 106p.

CNRST / Project Climate / study3 (2003). *Vulnerability and adaptation of water resources at the climate change in the Basins of the Sankarani and of Baoulé*, National Centre of Research and Technology, April 2003 Bamako Mali, 126p.

2.9 Mongolia

P. Batima[23]

2.9.1 Introduction

For Mongolia climate change and extreme climatic events could have dramatic impacts on its economy and natural systems, with the potential in some cases for irreversible damage to ecosystems. Agriculture, including crop and livestock production, water and forest resources, as well as biodiversity, are among the most vulnerable systems.

The Mongolian government perceives that any negative effects, which may be experienced from climate change, could be equivalent to a national disaster. Extreme climatic events with or without a superimposed change in climate could have tremendous adverse effects on the Mongolian economy and on the wellbeing of its people.

Moreover article 4 of the UNFCCC calls upon all Parties to prepare a National Action Plan on climate change that describe GHG inventories and an actions to reduce GHG emissions and to adapt to climate change. In addition, a National Action Plan (NAP) is necessary not only to meet country's obligations under the UNFCCC, but also to set priorities for action and integrate climate change concerns into other national environment and development plans. Therefore, Mongolia requested the Government of the Netherlands to assistant in preparation of its National Climate Change Action Plan.

The Mongolia study under the NCCSAP aimed to cover:

1. Analysis and evaluations of the GHG mitigation options;
2. Impact and adaptation assessment on the agricultural sector (crop production);
3. Impact and adaptation assessment on Rangeland and Livestock sectors; and
4. The preparation of the National Action Programme on Climate Change.

Hence the project expert team has completed impact and adaptation assessments for the natural resources that depend on water resources: permafrost, soil, grassland and agricultural activity as livestock, crop production as well as mitigation analysis of GHG. The National Action Programme on Climate Change was prepared on the base of results of these studies. Water is a cross cutting issue which is important for crop production, livestock husbandry and domestic use.

Water is crucial for the maintenance and restoration of the environmental carrying capacity of pasture/grassland and other economic activities such as crop growth. Thus wa-

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ter must be integral part of the total environmental management package. We believe that through water resources management, land use and human activities can be guided and controlled in Mongolia. Therefore, in this section we will focus on water.

Nearly half of the population lives in rural areas where people use wells, rivers, springs and other surface waters for daily use. The provincial centres also have a strong rural character i.e. most households grow crops and rear animals. Therefore, both urban households, and herdsman depend on the availability of water. But freshwater is a vulnerable resource. In some areas of the steppe and the Gobi, groundwater is the only source for daily use. Different types of wells (artesian, pipe, tube or hand) serve as water source for residential use and for livestock watering. Rivers are the main source of water for residents of mountainous regions. Herdsmen must decide to reconcile at places where water is available or where the herds can graze. For instance in the Gobi, herdsman families move 6-7 times a year to find a place where both water and pasture are available. The movement around water resources leads to an increased pressure on the land in the vicinity of the scares resources. The resulting high cattle densities in turn lead to overgrazing, trampling erosion and sand movement. Accordingly water shortage has become one of the major socio-economic problems, especially in the Gobi and the steppe.

2.9.2 Approach

Climate change scenarios

The scenarios of General Circulation Model (GCMs) were used to examine the impact of increased green house gases concentrations on future climate of Mongolia. The results of GCM scenarios have been downscaled from database of IPCC Working Group I. We used the scenario of IS92a, which takes only GHG concentrations. The five scenarios that selected for current study are 1) the Max Planck Institute of Hydrology and Meteorology of Germany (ECHAM4) model, 2) the Canadian Climate Center Model (CCCM), 3) the United Kingdom Meteorological Office and Hadley Centre (HADLEY) model, 4) the Geophysical Fluid Dynamics Laboratory (GFDL) model, and 5) the Division of Atmospheric Research Private, Australia (CSIROMK-2) model. The results of GCM scenarios were given in grid boxes of $2.8° \times 7.5°$. Therefore in order to find the changes in temperature and precipitation at the given/studying location use is made of two-dimensional interpolation. The values of temperature and precipitation are determined on grid boxes of $0.5° \times 0.5°$.

Sensitivity analysis

Here hypothetical and systematic changes in temperature and precipitation are used to test the sensitivity of the outcomes with respect to these two inputs.

Water Resources Study

The Basin Conceptual Model (BCM) was used to assess river runoff under climate change. The BCM is a balance model that uses a monthly time step and requires multi-annual monthly mean values of precipitation, temperature, potential evapotranspiration, and runoff as input. It takes the storage of the previous month to compute infiltration, evapotranspiration and runoff. It contains six parameters, with two of the parameters being the upper and lower temperature bounds on the freezing and melting process (Batima, 1995, 1996).

A split sample test was used to evaluate the hydrologic model. In this test the historic record is broken into two segments, one used for calibration and other for validation. Since the ranges of climatological and hydrological data for the selected rivers were different, the last 24 years are selected for model verification and testing. Particularly the first ten years (1972-1981) were used for calibration and the remaining fourteen years (1982-1996) were used for validation. The estimation of river runoff is done for each hydrological year. The hydrologic year begins in October, when snow accumulation is assumed to be zero. The estimated condition of soil moisture and snow pack at the end of each year is then taken as the initial condition of the calculation for the next year. The correlation coefficient and the average monthly error are used to describe model performance.

2.9.3 Results of the water resources assessment

Introduction

It is estimated that water resources in Mongolia amount to 34.6 km^3 from which 83.7%, 10.5% and 5.8% account for lakes, glaciers and rivers, respectively (Surface water of Mongolia, 1999). The total annual water use is 0.5 km^3 (MAP 21, 1999). Hence, the water use seems small compared to the water resources. However, water resources are unequally distributed over the country i.e. in the northern part of the country the available water per capita is 4-5 times more than the world average while it is 10 time less in southern part i.e. in the Gobi (Surface Water of Mongolia, 1999).

Twenty river basins of different scale and climatological characteristics were selected. Selection criteria included basin size, varying climatic and basin characteristics (hydro-climatic zones), as well as time series data availability. The climate baseline of water resources was based on the monthly mean temperature, the monthly precipitation, and the duration of sunshine hours for the selected twenty rivers.

Sensitivity analysis

With the set of hypothetical scenarios we have generated a series of results that gave insight in the sensitivity of the basin flows to climate variations.

As expected, river runoff is much more sensitive to the precipitation changes than to the temperature changes. The analysis indicates that if annual precipitation drops 10%, while the temperature remains constant, the average river flow is reduced with 7.5%, 12.4% and 20.3% in the Internal Drainage Basin (IDB), the Arctic Ocean Basin (AOB) and the Pacific Ocean Basin (POB), respectively. If, besides the precipitation drop, average temperature increases of 1°C, 2°C and 3°C are taken into account, an additional flow reduction of 3 - 11% is expected. In other words, it appears that for each °C temperature increase, there is a 2-6% annual flow decrease.

Table 2.1 shows results of the sensitivity analysis for the three basins mentioned above. As can be seen from the table, the POB is more vulnerable to changes in precipitation and temperature than the other two basins. Moreover the sensitivity analysis shows that the river flow in IDB rivers *increases* with increasing temperatures under constant precipitation levels. Since a glacier is the major source of river runoff formation for most rivers in the Mongol Altai and high altitudes in the Hangain mountains, and because the increased temperature would result in intensification of glacier melting, river runoff is likely to increase even when precipitation remains the same.

Table 2.15 Changes in river runoff at the three basins investigated (%).

	P-20	P-10	P=0	P+10	P+20
Internal Drainage Basin					
T+0	-20.2	-7.5	0.0	21.2	37.3
T+1	-17.3	-5.9	6.1	26.2	40.0
T+2	-20.2	-8.9	3.7	21.3	36.3
T+3	-22.8	-12.1	0.2	17.0	30.6
Arctic Ocean Basin					
T+0	-22.3	-12.5	0.0	12.8	27.4
T+1	-23.5	-14.1	-3.8	9.1	22.9
T+2	-27.2	-18.4	-9.3	1.9	14.5
T+3	-29.0	-21.6	-13.5	-3.0	7.9
Pacific Ocean Basin					
T+0	-29.3	-20.3	0.0	17.7	31.2
T+1	-36.9	-26.9	-15.1	5.0	21.2
T+2	-40.1	-31.9	-20.7	-5.5	8.2
T+3	-42.1	-31.6	-23.1	-9.8	6.1

The impact assessment

With similar scenario assumptions and driving forces, climate projections can vary considerably among GCMs. Therefore, to allow for critical comparisons, we analyzed a range of climate projections by five different GCM outputs. The results reflect the high uncertainties in the results of different climate models. Nevertheless, despite their limitations these model results provide a first indication of the general range of possible flow alterations due to climate change.

CCCM: According to this scenario the runoff of the rivers will increase by 18-124% in 2040. The highest increase is expected to occur in the rivers flowing from the southern slope of the Hangain mountain and the lowest in the rivers in the Uvs lake basin. However, the runoff of the Muren river that flows from the Huvsgul mountain will decrease by 0.3%. In 2040, the runoff of the Internal Drainage Basin, the Arctic Ocean Basin and the Pacific Ocean Basin, seems to increase by 56%, 50% and 65%, respectively. The CCCM result indicates substantial *decreases* in the water resources during the period 2040-2070.

GFDL: In this scenario the runoff of the rivers will increase by 10-90% in 2040. The highest increase seems occur in the Pacific Ocean Basin and the lowest in the Arctic Ocean Basin. The river runoff in period of 2040-2070 is expected to be 2-24% higher compared to the current runoffs, 15-38% lower compared to 2040. In sum, the river discharges in Mongolia expected to increase in until 2040 and most likely to decrease in the period 2040-2070.

ECHAM 2: In this scenario, the river runoff is expected to change from *minus* 25.1% to plus 114% in 2040. The increase in river flow would occur in all rivers in the Arctic and Pacific Ocean Basins. There is going to be a decrease in river flow by 10-25% in the rivers flowing from the northern slope of the Mongol-Altain mountain and the rivers in the Uvs lake basin. This scenario indicates that the water resources in the Arctic Ocean Basin would remain almost the same in the period of 2040-2070 compared to 2040, in the other two basins the water recourses seems to decrease by about 18%.

HADLEY: According to this scenario the river runoff likely to increase by 3-65%. The highest increases seems to occur in the Pacific Ocean Basin and the lowest in the Arctic Ocean Basin, which was also found in the other scenarios. The river flow appears to continue to increase in the period 2040-2070 in the Arctic Ocean and the Internal Drainage Basin by about 11% compared to 2040, whereas the river flow in the Pacific Ocean Basin expected to decrease by 19%.

The scenarios show that Mongolia's water resources are most likely to increase until 2040 and then would decrease until 2070 towards the current levels. For example in the Internal Drainage Basin the river runoff expected to be 5-120% higher in 2040 compared to the current runoff. Especially CCCM and CSIROKM2 give very high increases in river runoff. But after 2040, it is going to start to decrease again. The river flow patterns strongly follow the temperature and precipitation patterns. According to the climate change scenarios after 2040 temperature is expected to continue to increase, while precipitation starts to decrease. If this pattern will continue, it is clear the water resources will continue to decrease from 2040.

The scenario results also show that global warming will not significantly influence the seasonal distributions of the river flows (Figure 2.12). About 60 to 80% of the annual water runoff is formed during the rainy season. About 80% of all rainfall comes down in 2-4 intensive showers. They cause high flows, which run away quickly and their contribution to water storage is therefore negligible. From the sensitivity analysis we found that the river flows are more dependent on precipitation than on temperature.

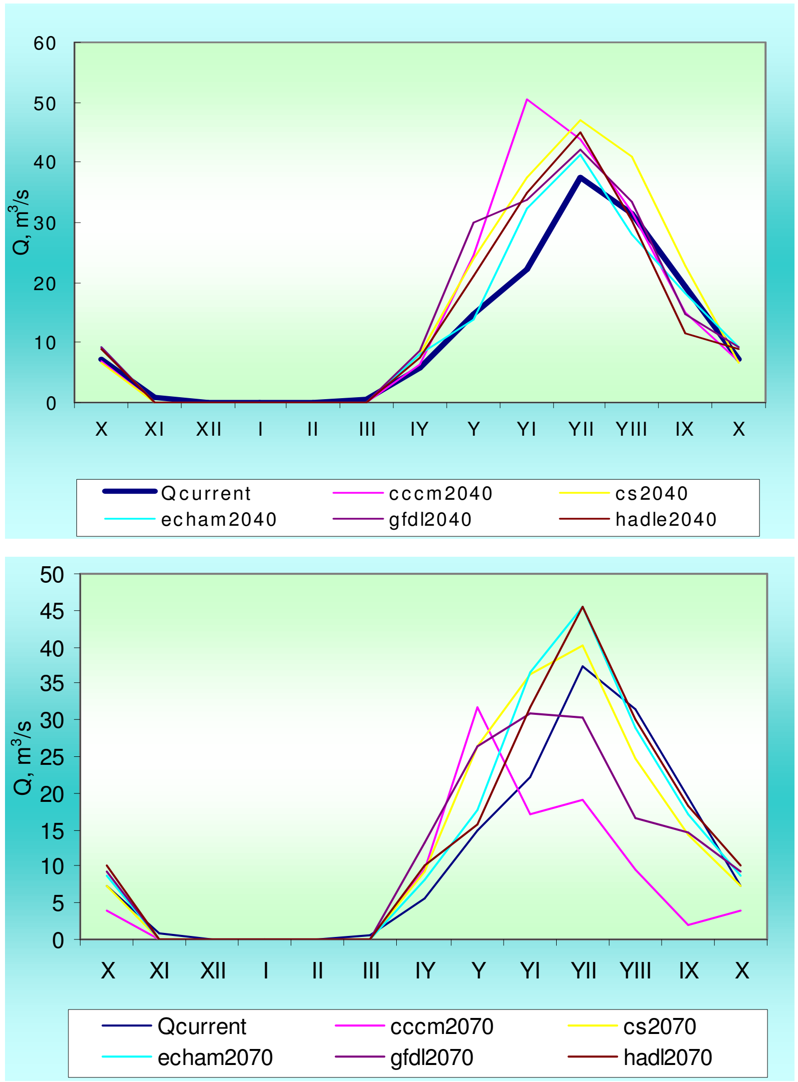

Figure 2.12 Current and simulated monthly runoff by the five GCM scenarios at the Tuul river in 2040 (top) and 2070.

General adaptation measures

Taking into account the existing scarcity of natural water supplies and their anticipated alterations, some adaptation measures we should consider are:

- The results from the climate change analysis as presented above show future flow alterations. Whatever scenario considered, the presented climate change analyses strongly suggest that significant effects in the form of altered flow regimes, regardless of decreasing or increasing trends, may put additional pressure on the river water system. In consequence, a prospective strategy for water resources management needs to include the entire range of climate change scenarios. Hence, it is clear that traditional water resources management and development approaches and technologies no longer can provide sustainability of water resources. Accordingly, new, integrated approaches are needed to reconcile conflicting interests on the use and the conservation of water resources. Thus, one of the most important adaptation measures is to prepare our next generation of water managers and to create the scientific, technical, institutional and organisational capacity to deal with the effects of climate change. To elaborate a comprehensive management strategy and to train national experts, it is necessary to implement national and international projects funded by the government and international organisations;

- It is important to apply a water resources management policy that focuses on the rational use of available water resources without exceeding their renewal rate. In particular, the conservation of freshwater ecosystems in runoff formation zones is an essential element for water resources management, because these areas largely determine the sustainable recharge of groundwater and surface water storage. In order to reach this goal, it is necessary to incorporate the upper areas of the basin runoff where most of the water originates;
- Water quality may be more important than the water quantity since available water often does not meet the drinking water standards. Recently, most of the river waters are assessed as fresh by the water quality requirements (Batima, 1998). There are several important options such as the improvement of the operation of waste water treatment plants to reduce pollution, maintenance of sanitation zones to protect river water quality, development of the water recycling technology, organization of chemical as well as biological monitoring to control and predict water quality, etc.;
- The Dublin International Conference on Water and Environment (WMO, 1992), emphasised, that water should be considered as an economic good (see also section 4.3.2). Water use/supply for animal watering and irrigation is still free in Mongolia. People do not care about commodities that are supplied for free. Therefore, the issues of conservation of water resources and demand side management should be highlighted in the future through public awareness and training. The intensity of precipitation is going to increase due to climate change and, consequently, flood events will increase. At the same time, in low precipitation areas, the drought occurrence might increase. In this respect, studies on the physical condition and prediction of such events can be a significant adaptation option to overcome the possible hazardous impact of climate change. Waters in the Gobi-desert are naturally saline and will become more saline under increased temperature. Hence, water softening and purifying equipment is needed to provide safe water supply.

2.9.4 Experiences and lessons learned

Working with models and scenarios

The Water Balance Equation was found to be an efficient tool for the climate-water resources impact assessment (Zdzislaw, 1994). After consideration of a number of standard models such as CLIRUN3, WatBal and the Basin Conceptual Model (BCM, Yates and Strzerek, 1994), the latter was selected for the study. One distinguishing characteristic of Mongolian rivers is that all of them are covered by thick ice layers of about 1.0-1.8 meter for five or six months a year during and small rivers are even frozen to the bottom. The initial form of the Basin Conceptual Model did not give good results. Therefore, we have made some modifications (adding coefficients as on snow melting and surface runoff) in finding of snow accumulation and estimating of basin runoff for both seasons (Batima, 1995, Batima *et al*., 1996).

Hydrological, meteorological and socio-economic data were used for water resources assessment. Although the length of the time series was rather short to show the trends of water resources of past climate change, it was sufficient to model the river runoff.

The simulation results obtained with climate scenarios were compared with the actual observation data. It was found that the estimated runoff exceeds the observed one by 0.01-5.5 percent in most of the rivers. In few river like Sagsai, Ylz, Herlen and Yrdtamir it is underestimated by 0.1-3.4%. In spite of these errors, the estimated runoff has a rather good correlation with the observed one for each selected river basin. The correlation coefficient between simulated and observed runoff was between 0.66-0.86 and the average monthly error between 0.27-7.49. These statistical values are well enough to conclude that the BCM model performs well in exploring current situation and that it can be used for simulation of river runoff with climatic variabilities. The high significance levels of the statistical values derived during calibration and validation can be explained by assumptions made on the base of nature of the monthly mean runoff, i.e. the strong seasonality with high flows during the rainy season and the freezing of the rivers in the winter.

Multi-disciplinary research in the studies

The Technical Expert Team (TET) included experts from relevant sectors including government agencies, academic institutions, and private companies, including the Ministry of Nature and the Environment (MNE), the National Agency for Meteorology, Hydrology and Environment Monitoring (NAMHEM), the Institute of Meteorology and Hydrology (IMH), the Ministry of Agriculture and Industry (MAI), the Ministry of Health and Welfare (MHW), the Ministry of Infrastructure and Development (MID), the Institute of Geo-Ecology (IGE), the Institute of Biology (IB), the Mongolian National University (MNU) and the University of Agriculture (UA).

The TET had divided itself into three sub teams, namely, the team of preparation of NAPCC, the team on analysis and evaluations of the GHG mitigation options, the team on impact and adaptation assessment in the Agriculture sector (crop planting) and the team on impact and adaptation assessment in the Rangeland and Livestock sectors. However we recognise that the constitution of TET was biased towards the scientific community, we should have invited also some NGOs to get additional inputs.

Limitations

The spatial grid of the GCM outputs is relatively course compared to the river basin scales. Therefore, it could be that the modelled outcomes are relatively uncertain. Furthermore, a prospective strategy for water resources management needs to include the entire range of climate change scenarios.

The BCM was used to estimate changes in water, it does not provide detailed analysis of micro-level processes, which may be where most of the impacts of climate change occur. The model does not provide information on floods, droughts, or other extreme events. Also, groundwater impacts are not addressed in regard to impacts on recharge or as an alternative to surface resources. The melting of glaciers was also not taken into account with this method.

Adaptation options have been evaluated mainly on the base of expert judgement. Therefore, we are aware about the small scientific base of the discussion and as a result the indicated adaptation options were rather subjective. A screening matrix to examine the adaptation options and evaluate their suitability for implementation has been used for the first time in the study (Climate change and its impacts in Mongolia, 2000).

The study created a framework for subsequent mainstreaming of climate change issues in the national policy and legal framework. It has enhanced capacities in the scientific and research community of Mongolia to appreciate climate change issues and further work on them in the context of its results. The project has further highlighted the need for a stronger effort of creating awareness among the stakeholders and decision makers.

2.9.5 Follow-up research

The results presented here cover the changes of river runoff. The other hydrological parameters as river ice trends and river flow changes in different water regimes have not been studied. Thus the results should be considered a starting point for more detailed discussions about anticipated climate and global change effects on not only water resources but also freshwater ecosystems. Additional studies are required to validate the results. From an ecological perspective, it is important to identify quantitative thresholds that mark the limits of alteration to which an ecosystem can adapt. In this context the Mongolia project has been able to create a solid foundation for further work on scientific and policy issues. It clearly defined the issues that are relevant within the national context, and identified potential areas for further research.

After the completion of the NCCSAP project Mongolia has developed the project under initiation of Expended financing for (interim) measures for capacity building in priority areas of the GEF Climate Change Enabling Activity (Part II) in order to provide contribution in the implementation of the National Action Plan on Climate Change (NAPCC). The project focus was *Assessment of Technology Transfer Needs in Mongolia Energy Sector, Public Awareness and Education, Enhancement of National capacities to Prepare National Communications.*

Through implementing this project Mongolia has achieved:

1. *An Assessment of Technology Transfer Needs in the Mongolian Energy Sector.* Beside training of engineers and managers in industry and Heat Only Boilers (HOBs), a technology needs assessment was done in more than 100 industries in food processing, wool and cashmere manufacturing, building material production and texture production as well as in other sectors. As a result of this work, which concerned inefficient HOBs, the Government included this as one of the pillars for its Strategy to Donors at the CG meeting in July 2002. As a follow-up, the International Donors Agency is identifying components of it for its next lending support;
2. *Public Awareness and Education.* Three books as ‘Climate change’ and ‘Green house gas and its effects’ and ‘Climate change and sustainable development’ have been written and published in Mongolian for the undergraduate, graduate and post graduate students, and two information kits named ‘GHG emission and its mitigation’ and ‘Climate Change’ were published in Mongolian for a wide public audience;

3. *The Enhancement of National capacities to Prepare National Communications*. A national climate change website was established. It was designed for the distribution of the information and results that were produced in past and ongoing climate related activities in Mongolia. The most important books, brochures, information kits, posters, articles and presentations that were produced have been published on this website.

Research on *Potential Impacts of Climate Change and V&A Assessment for Rangeland and Livestock in Mongolia* is currently being carried out within the Assessments of Impacts of and Adaptation to Climate Change in multiple regions and sectors (AIACC) programme.

2.9.6 Policy implications

The Government of Mongolia approved the National Action Programme on Climate Change on 19 July 2001. The Ministry for Environment and Nature organised National Workshop on Climate Change Issues in Mongolia on 27-28 June 2002 in Ulaanbaatar. The objective of the workshop was to draw the attention of stakeholders at different level (policy and decision making, research and educational institutions, NGOs, private sector and the general public) on the implementation of NAPCC and disseminate and discuss climate change issues such as greenhouse gas emissions and mitigation, expected climate change impacts, vulnerability and adaptation in different sectors of the country. 160 delegates participated including eight members of parliament, 33 officers from different ministries and agencies, 42 delegates from 21 provinces, 26 delegates from research and educational institutions, 40 delegates from private companies and NGO's and 11 journalists. Box 2.1 presents a citation of a part of the Minister's speech at this workshop.

Box 2.4 Citation from the Minister on the National workshop on Climate change.

> Almost one third Mongolia is defined as a very vulnerable region under climate change. All rivers in this region are seasonal i.e. they have flow only during the rainy season. Nearly 90% of the lakes have an area of less than 1 km^2 and strongly depend on precipitation. The residential water demand can be met by ground water in towns, villages and settlements but the pasture water supply will be the most difficult problem to solve, particularly in arid and semiarid areas. Therefore, further water resources study under climate change should focus on this vulnerable area.

As a follow-up of this National workshop local and sectoral workshops on climate change issues have been organised. Particularly, a regional workshop in the eastern province was organised by local governors and local specialists. Main goal of this workshop was to discuss how to integrate climate change issues in regional development.

Similarly, a workshop titled 'Climate change and Agriculture' was organised by organisations such as the Plant Science and Agriculture Training and Research Institute at Darkhan, the Institute of Meteorology and Hydrology, the Association for agriculture farmers and Flour producers, the Canadian Agroteam Co. Ltd, the Agriculture Development Fund and the National center for technology renovation in agriculture. Participants discussed how to set the adaptation options included in the NAPCC into arable land development.

2.9.7 Conclusions

There are four main climatic water regimes observed in the rivers of Mongolia. These are: *winter low flow period; spring runoff period due to snow melting; summer runoff period due to rainfall; warm season low water period.* Due to the unequal distribution of precipitation and the sharp changes of seasons, the water resource varies significantly across time and space.

The sensitivity analysis indicates that if annual precipitation drops 10%, while the temperature remains constant, the average river flow reduces by 7.5%, 12.4% and 20.3% in the IDB, the Arctic Ocean Basin and the Pacific Ocean Basin, respectively. If, besides the precipitation drop, the average temperature increases of 1°C, 2°C and 3°C are taken into account, an additional flow reduction of 3 - 11% is expected. In other words, it appears that for each °C temperature increase, there is a 2-6% annual flow decrease.

The GCM based scenarios results show that Mongolia's water resources are most likely to increase until 2040 and then will decrease until 2070 towards the current levels. For example in the Internal Drainage Basin the river runoff expected to be 5-120% higher in 2040 compared to the current runoff. Especially CCCM and CSIROKM2 give very high increases in river runoff. But after 2040, it is going to start to decrease again. The river flow patterns strongly follow the temperature and precipitation patterns. According to the climate change scenarios after 2040 temperature is expected to continue to increase, while precipitation starts to decrease. If this pattern will continue, it is clear the water resources will continue to decrease from 2040. This suggests that it will be worthwhile to take water storage in the period 2000-2040 into account.

The GCM scenario results are confirmed by the sensitivity analysis results: especially at high altitudes, the river flows tend to increase with temperature if precipitation is unchanged. This is most likely expected to happen during the first decades of the global warming scenarios.

Surface water resources are expected to decrease after 2040. The rate of decrease is higher in the eastern part than in the western part. This may be caused by changes in natural zones and permafrost shift. The cool temperature zone in the Hentein mountain region will be reduced drastically in 2040 and will be replaced almost completely by the warm temperature zone in 2070. The permafrost boundary will rapidly shift to the north and permafrost will be nearly disappeared in 2070.

Projected increases in air temperature will lead to severe changes in snow and glacier melt. The effects of this change are highly difficult to predict. It also should be kept in mind, however, that the melting of the glaciers cannot be considered a sustainable process, but rather represents a non-renewable water resource that is limited by the individual glacier volumes. The effect could be from increased average flows increasing until the entire glacier is melted, then decreased flows. This may cause earlier and intensified high flows from snowmelt during spring that followed by extended and more pronounced low flow periods.

Main products

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2.10 Senegal

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2.10.1 Introduction

Senegal was among the first Non Annex I Parties of the UNFCCC to present its Initial National Communication in 1997 (Republique du Senegal, 1997). The first study, which started in 1990, assessed the impacts of sea level rise on the Senegalese coastline (Dennis *et al.*, 1995). The second study was part of country studies on global food security and climate change conducted in Zimbabwe, Kenya, Senegal and Chile (Downing, 1992). These two studies were funded by the US Environmental Protection Agency. The choice of Senegal was in fact determined by the results of a first Global Vulnerability Analysis that was made by the Intergovernmental Panel on Climate Change / Coastal

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Zone Management Subgroup to test the Common Methodology relative to the impacts of climate change in the coastal zones (IPCC/CZMS, 1991). In this study Senegal was ranked as the 8^{th} most vulnerable country to sea level rise among 181 countries (Hoozemans *et al.*, 1993). Senegal was thus chosen to conduct pilot studies on the impacts of climate change on their coastal zone and on agriculture.

In Senegal, three studies were conducted under the NCCSAP: the development of a national climate change scenario (Gaye *et al.*, 1998) and two V&A studies for agriculture and coastal zones. This choice for the sectors was determined by their economic importance for the country as well as by the existing expertise in the country. This paper presents the results of the V&A study for the coastal zone because it is a relative comprehensive study.

During the same period three other V&A studies were developed: one on water resources, one on fisheries and the last one on tourism as part of the UNITAR CCTrain programme. It is important to notice that Senegal developed an implementation strategy for the Climate Change Convention in 1999 (Republique du Senegal, 1999).

The 1990 coastal zone V&A study only assessed the impacts of different scenarios of sea level rise –namely coastal erosion and inundation- on all the coastline with rough estimations of population and land value at risk as well as an evaluation of the costs of adaptation, mainly protection. Within this context, the main purpose of the NCCSAP funded study on the impacts of climate change on the Senegalese coastline was to develop a more comprehensive and integrated picture of the coastal vulnerability to climate change.

2.10.2 Approach

Based on the results and experiences of the 1990 V&A study, it was decided to include the following improvements in the NCCSAP funded study:

- Consider case studies that are representative for the main coastal environments. Two geographic locations were chosen: the Cap Vert peninsula which is an example of an highly urbanised coastal zone and of sandy coasts; the Saloum estuary which is representative of a mangrove estuary the second major coastal environment in Senegal;
- Use of a multidisciplinary approach by building a team constituted of 11 Senegalese experts from different fields;
- For each case study, consider not only the impacts of sea level rise but also other potential climate change impacts such as changes in rainfall, temperature and upwellings;
- Perform a more comprehensive assessment of socio-economic impacts by using socio-economic scenarios and discount rates;
- Have a broader approach of adaptation to enlarge the basic solutions developed by the IPCC/CZMS: retreat, accommodate, protect (IPCC/CZMS, 1990).

The study used a mix of methodologies ranging from simple expert judgement to the use of simple and complex models: such as the Bruun rule to calculate the land losses due to coastal erosion and the FEFLOW model to evaluate the impacts of climate change on the position of the salt water intrusion in coastal aquifers (Faye *et al.*, 2001). The IPCC methodology (Carter *et al.*, 1994) and the UNEP handbook on methods for Climate

Change and Impact assessment and Adaptation strategies (Feenstra *et al.*, 1998) were used as basic methodologies in the project.

2.10.3 Results of the coastal zone study

In this section we will first give an introduction to the two case study areas. Then the main results of the V&A study will be presented.

The Cap Vert peninsula

The geographical delimitation of this case study was made to include three components: 1) the metropolitan area of Dakar; 2) part of the north coast, characterised by major dune systems inside which are interdune lows, the *niayes*, partly inundated by the coastal aquifer and 3) part of the south coast where the sandy coast is bordered by a single barrier system and occupied by a number of villages and small towns. The total area considered is 1,597 km^2. In 1992, the total population was 2.3 million inhabitants representing 30.5% of the total population and 60% of the coastal population. During this year, the activities in the study area contributed to 37% to the national GDP, mainly from the services and industrial sectors. Economic activities linked to the coastal zone are fisheries and market gardening that takes place in the *niayes*.

The Saloum estuary

This is a complex estuarine system comprising three main rivers: Saloum, Diomboss and Bandiala with numerous small tidal channels. All of them are bordered by mangrove forests along their downstream parts. The Saloum river is bordered by a long sand spit: the Sangomar sand spit of 15 km long. The total area covered by this second zone is 4,309 km^2 most of it 2 m below sea level. In 1992, the total population in the estuary was 540,000 inhabitants (7.2% of the national population and 14% of the total coastal population). This population is distributed in two middle size towns (Kaolack and Fatick) and a great number of small villages. The main activities in the rural areas are fisheries, agriculture and tourism. It was estimated that these activities in the estuary contributed for 12.3% to the national GDP in 1992.

Main biophysical impacts

In the two case studies, it was possible to determine land losses due to coastal erosion and inundation but also impacts on coastal aquifers, vegetation, and on halieutic resources. These are elaborated below.

Land losses due to coastal erosion and inundation

Land losses due to erosion were determined by applying the modified Bruun rule (Nicholls *et al.*, 1995). For land losses due to inundation the formula proposed by Hoozemans *et al.* (1993) was used. Three inundation levels were defined: minimum inundation levels by 2050 and 2100 and a maximum inundation level by 2100. The results are presented in Table 2.16.

Table 2.16 Land losses due to coastal erosion and inundation (in km² and percent of the total beaches in the area).

	2050	2100
Land losses due to coastal erosion		
Cap Vert peninsula	0.24-1.79 km^2 (3.8-28.5%)	0.77-3.95 (12.2-62.8%)
Saloum estuary	0.07-1.82 km^2 (4-109%)	0.19-4.02 (11.4-241%)
Land losses due to inundation		
Cap Vert peninsula	48-57 km^2 (3-3.5%)	397.7 km^2 (25%)
Saloum estuary	896-1690 km^2 (27-52%)	2,911 km^2 (89%)

The beaches found to be most vulnerable to sea level rise are those located south of Dakar where the sand availability is limited. This confirms the conclusions of the previous V&A study (Dennis *et al.*, 1995). Small towns as well as fisheries and industrial infrastructures densely occupy this part of the coast. The Sangomar sand spit seems particularly vulnerable since it could disappear by 2100 with the maximum inundation level scenario. Since the sand spit is protecting the whole estuary, its disappearance will have major consequences for systems in the estuary.

Inundation in the Saloum estuary could include 27% of the land and about 50% of the mangrove area by 2050. With higher inundation levels all the deltaic plain could be inundated leading to the estuary being restricted to islands corresponding to old barrier islands that are the highest parts of the estuary. Major communication problems will arise in this situation since important portions of roads will be flooded. In the Cap Vert peninsula, areas that are likely to be inundated are much more limited but they are places of dense human occupation. Hence, the socio-economic consequences will be significant.

Modifications in coastal aquifers

Coastal aquifers, which form a major source of fresh water all along the coast, will be affected by any change in precipitation, reducing the recharge, and by sea level rise, which will increase salt-water intrusion. This situation will worsen by the expected increase in population.

From the expert judgement and based on a climate change scenario (diminution of precipitation between 1 and 10%; rise in temperatures comprised between 1 and 3.5°C and a 0.5 m sea level rise by 2050), it appears that the piezometric level will be lowered and that the recharge will decrease while salt water will progress inland. These changes will have important impacts on the *niayes* since their location depends on the piezometric level. It is expected that some will disappear and others will be created. Along the coastal lakes, the freshwater reservoirs will be reduced. In the Saloum estuary, the salt-water intrusion will be increased by the salinisation of the river.

The results obtained on the Dakar aquifer with the FEFLOW model, using a 0.5 m sea level rise and a 10% reduction in the natural recharge, show a net progression of the salt water interface that will contaminate part of the harnessing field used for fresh water supply of Dakar (Faye *et al.*, 2001).

It must be also noted that the increase in water demand due to population growth was not considered in this analysis. Thus, the water deficit is likely to be even larger.

Impacts on coastal vegetation

Two types of vegetation were considered: the coastal vegetation along the north coast and the mangrove in the Saloum estuary.

Based on a comparison with the evolution of the flora with drought (Hubert, 1917; Trochain, 1940; Raynal, 1963; Michel *et al.*, 1969) it can be expected that along the north coast species not adapted to a rise of temperature (mainly the hydrophile flora and in particular the relictual guinean flora) will disappear and the flora occupying the humid environments (lake sides for example) will be replaced by flora adapted to drought, salinity (halophytes) and new soil textures (more sandy due to the increase in aeolian erosion).

The mangroves present in the Saloum estuary are already close to their physiological limits especially for salinity (Diop and Ba, 1993). It is considered that temperature and rainfall changes will probably affect the phenology of the species. Regarding sea level rise, it will act indirectly, mainly by the processes of erosion and sedimentation it will induce. The experience with the recent breaching of the Sangomar sand spit indicates that changes in soil texture (becoming more sandy) due to massive influx of sands coming from coastal erosion of the spit have much more impacts on the mangrove because they impede its reproduction cycle (seeds cannot germinate in sandy soils). An increase in salinity could also disadvantage the mangrove trees. Moreover, it is considered that with a 0.2 to 0.5 m sea level rise, the mangrove could slowly migrate inland but that a rise of 0.86 m will have more important consequences with for example changes in the zonation of the mangroves and difficulties to migrate.

Impacts on halieutic resources

In the open sea, the main consequence of the oceanic warming will be a decrease in the intensity of the coastal upwellings (Mitchell, 1988; Tsyban *et al.*, 1990) which is confirmed by palaeoceanographic studies (Lapenis *et al.*, 1990) as well as by recent records of inter-annual variability in the intensity of upwellings linked with changes in oceanic temperatures (Oudot and Roy, 1991). This will induce reduction in the productivity of oceanic waters that is the major support for fisheries. This, combined with the potential disappearance of some mangroves and oceanic warming, will affect the halieutic resources in line with the observations made in years with less intense upwellings and low halieutic productivity (Oudot and Roy, 1991). In fact, the main resources on which fisheries are based like tuna, groupers, small pelagics will be affected inducing changes in species composition with, for example, apparition of species which prefer warmer waters like *Balistes carolinensis*.

In the estuaries, halieutic resources will be mainly affected by the destruction of mangroves which, in first instance will enrich the estuaries but by the time will reduce primary production. These mangroves are used as nursery and breeding grounds for a number of species and in particular shrimps by other pelagic resources which use mangroves in one or another part of their life cycle.

Main socio-economic impacts

For each of the case studies, the population and the economic value at risk were assessed considering the different inundation levels and socio-economic scenarios as well as discount rates (3 and 6%). The main results are given in Table 2.17.

Table 2.17 Socio-economic impacts of inundations and costs of adaptation.

	2050	2100	
Inundation levels	Minimum	Minimum	Maximum
Population at risk			
Cap Vert peninsula	109,000	730,000	4,700,000
Saloum estuary	74,600	847,000	11,800,000
Economic value at risk with a 3% discount rate in billion CFA F (billion US$*)			
Cap Vert peninsula	182 (0.26)	3,000 (4.33)	21,000 (29.32)
Saloum estuary	160 (0.23)	2,800 (3.94)	38,000 (54.49)
Costs of adaptation with a 3% discount rate in billion CFA F (in billion US$*)			
Cap Vert peninsula	8.3 (0.01)	2.9 (0.004)	17.8 (0.03)
Saloum estuary	170 (0.24)	40.6 (0.06)	41 (0.06)

* exchange rate 1 US$ = 700 CFA F in 2001

The total population at risk in the two case studies, the people at risk in the estuary and the people at risk at the Cap Vert peninsula, varies between 180,000 and 16 million (between 1.2 and 12.4% of the total population for the Cap Vert peninsula alone). The population at risk estimates are more accurate than those found for the total Senegalese coastline during the first study (Dennis *et al.*, 1995) mainly because in the first study population growth was not considered.

In terms of economic impacts, the main components at risk are private houses and agricultural production. The economic value at risk with a discount rate of 3% varies between 342 and 59,000 billion of CFA F (0.49 and 83.8 billion US$), which is also much higher than the values at risk determined in the first study.

Moreover, the impacts of climate change on fisheries will be determined by the reduction in resources as well as by the increase in extreme events and coastal erosion which will affect some infrastructure. This in turn could induce increases in the price of fish - with consequences on food security, in particular for the poorest - and loss of revenues.

Adaptation options

First of all two types of coastal protection were considered: sea dikes - mainly for urbanised and industrialised areas - and dune afforestation for coastal zones not yet densely occupied. In the two cases costs of adaptation are lower than the economic value at risk as can be seen in Table 2.17. This is a completely different result from the previous study that concluded the reverse, which can be explained by an underestimation of the economic value at risk in this former study (Dennis *et al.*, 1995). The new results indicate that protection measures should be considered especially for the parts of the coasts that are particularly important in terms of infrastructure and population, such as towns and harbours.

Since these measures would not solve all the consequences of climate change other adaptation measures were considered such as an integrated coastal zone management plan, a better management of all coastal and marine resources (water, flora, halieutic resources), rehabilitation of salted soils in the Saloum estuary, legislative and institutional arrangements and the creation of a research centre. However, no cost estimations were made for these options.

2.10.4 Experiences and lessons learned

This V&A study was a very rich experience. It was the first time such a study was conducted by a Senegalese team and with a multidisciplinary approach. Most of the members considered that they learned a lot from each other during this work that lasted almost 3 years. This exchange of experience not only led to new skills but also to ways of thinking differently than from a specialised approach. Regular meetings of the team contributed greatly to this and exchanges were very fruitful for all the members. We had the chance to discuss our ideas and approaches to define a common approach.

Of course, this study had its own limitations. We had to rely heavily on expert judgement mainly because some models were not available (i.e. for vegetation evolution) and data availability was limited. The models used were the Bruun rule and the more complex FEFLOW model. These were adapted to the specific circumstances for the case study by an expert who had the necessary data and experience to run the model. Another limitation was the fact that tourism was not considered in this study. Moreover, the qualitative nature of most of the evaluations limited the scope of the identification of economic impacts on for instance fisheries and tourism. Hence the economic evaluations should be considered as underestimations.

It was also the first time that this kind of study benefited from a public communication. Of course, it has been limited to a restitution workshop where major stakeholders were represented but the media gave much attention to the subject. This is interesting since at the beginning of the IPCC work and UNFCCC negotiations the feeling was that climate change was somehow too difficult to explain to the general public. Certainly this work helped to improve the way decision makers and the public are informed on climate change issues. This can partly explain why, few years later, a former Minister of the Environment explained what was climate change to an almost illiterate audience and it was surprising to see how people clearly understood the key issues. The public awareness was also enhanced by new climate extreme events, such as the cold and rainy event, which affected the northern part of Senegal in January 2002. This event was completely unexpected and induced serious damages to private houses, agricultural land and life stock.

2.10.5 Follow-up research

Unfortunately, the study was not followed by a new research project. This, combined with financial problems, induced a dispersion of the research team. From all the team members only two could continue research work on climate change issues. One researcher is actually engaged in a thesis work on the modelling of the Saloum estuary aquifer including considerations of climate change. The other just started a V&A study on the impacts of sea level rise on the Senegal delta. The others experts went back to their former research field.

It is also noticeable that the expert that developed the climate change scenario is actually the principal investigator of an AIACC (Assessments of Impacts and Adaptations to Climate Change) project responsible for the development of regional climate change scenarios for the Western Sahel.

However, the limitations indicated show that further research is needed in areas such as: the integration of tourism and fisheries in the economic evaluation and the assessment of other methods to protect the shoreline (example beach nourishment, which was not possible to examine due to lack of data). It is also important that some protection techniques that are currently not used in Senegal be tested before any large-scale implementation.

2.10.6 Policy implications

The study did not conclude on concrete policy measures with the exception of the implementation strategy where coastal protection and management is suggested as a short-term option. A first order project proposal to test coastal protection methods is given in the first National Communication of Senegal (Republique de Senegal, 1999).

Senegal lacks the funds to develop new adaptation study projects. It is considered that financial resources for further projects must mainly come from external sources, with the national budget being used for other urgent needs.

It is expected that the second phase of the NCCSAP will allow concrete actions to be developed in order to go beyond these previous studies.

2.10.7 Conclusions

The V&A studies conducted under the NCCSAP were a successful experience not only in terms of results but also for a better comprehension of potential impacts of climate change as well as for the multidisciplinary approach that was developed. Real progress was made in the understanding of the complexity of the vulnerability of our country to climate change.

The main biophysical impacts include land loss due to erosion and inundation, and salinisation of surface water and aquifers. In the areas studied it was estimated that in 2050 over 180,000 people are at risk and that the value at risk will amount approximately half a billion US$. Adaptation options include coastal protection, dune afforestation and integrated coastal zone management. Costs of adaptation were estimated to be 0.25 US$.

Main products

Niang-Diop, I., Dansokho, M., Diaw, A.T., Diouf, P.S., Faye, S., Gueye, K., Guisse, A., Ly, I., Matty, F., Ndiaye, P., Sene, A. (2000). *Etude de Vulnérabilité des Côtes Sénégalaises aux Changements Climatiques.* NCCSAP/Ministère de l'Environnement et de la Protection de la Nature, Dakar, 151 p.

République du Senegal (1997). *Communication Initiale du Senegal a la Convention-Cadre des Nations-Unies Sur les Changements Climatiques (CCNUCC)*, Ministère de l'Environnement, available from http://unfccc.int, 118 pp.

République du Senegal (1999). *Stratégie Nationale de Mise en Œuvre (SNMO) de la Convention Cadre des Nations Unies sur les Changements Climatiques (CCNUCC)*, available from http://unfccc.int, 53 pp.

2.11 Suriname

Cor Becker[28]

With the signing of the Rio Convention in 1992 Suriname became the 112th party to the UNFCCC, committing herself to meet her international obligations through presenting an inventory on Greenhouse Gases and impacts of climate change to the Convention. Suriname welcomed the financial and technical support of the Netherlands government to start with the project 'Country Study Climate Change Suriname (CSCCS)'. This project started in 1997, prior to the ratification of the Convention by the Suriname Government, and finished in 2000. Two main objectives were formulated for this project: the first objective of the CSCCS study was to produce a first national inventory of greenhouse gases, determined by the obligations following from signing the Convention, and, the second objective was to map the vulnerability of the coastal zone to sea level rise (SLR). Both studies were carried out for the base year 1994. Emphasis was on the second part of the project since many natural and socio-economic systems were expected to be disrupted or to malfunction due to sea level rise.

In the recent decades Suriname experienced an ongoing attack from the Atlantic Ocean over the largest part of her coastline, which, except for a few kilometres, is protected by mangrove forests. At certain locations along the shoreline, e.g. the coast of district Coronie, erosion has reached dramatic levels causing large-scale inundation and sudden changes in the local ecosystems. This resulted in degradation of the living environment for fish, shrimps, birds, turtles and other species in the coastal area. In addition, expanding areas of agricultural land and urban areas are affected by degradation of the coast. With the main population (±90%) living in the flat and low lying coastal zone Suriname is highly vulnerable to climate change impacts through sea level rise.

The studies contributed to capacity building on climate change issues and raised the awareness of policy makers and the public on the threats of climate change, in particular that of the sea level rise. Moreover, the study results emphasised the need to implement Integrated Coastal Zone Management. In addition, policy makers were advised to initiate policies and measures to cope with climate change problems, for instance to establish necessary institutions and support systems for short-term and long-term policy development.

2.11.1 Approach

The IPCC 'Common Methodology' (Carter *et al.*, 1994) was used as the basic approach in the study. The project started with the preparations of an inception report and detailing the methodology for Suriname. For the description of the impacts of SLR the coastal profile was determined based on existing data and some field measurements. In order to

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calculate the risk of SLR and to indicate the regions at risk a future coastal profile was determined. Because of the limited documentation on the future development of the country, the framework of the future profile was based on generally accepted theories and expert judgment. A GIS based flooding and flood risk model was used for the vulnerability and impact assessment.

To analyse the vulnerability and impacts in more detail a pilot study was scheduled within the project. One of goals of this pilot study was to train the staff in coastal zone management issues with respect to climate change. The pilot study also analysed promising adaptation measures. The results of the flood risk model were discussed in various workshops with different stakeholders such as scientific experts, policy makers, NGOs and others. The last national workshop in the project also identified and discussed possible follow-up project with respect to climate change and coastal management.

2.11.2 Results of the coastal zone management study

At the start of the study, little knowledge on the climate change issue and its possible impacts was available in the country. The concept of sea level rise and its consequences for coastal areas were unknown to many policymakers and scientists. Only limited, very widespread and ‘hard to reach’ data, mostly not digitised, was available. Especially topographical information was lacking. Some information was known to exist, but it would take a special project to collect and digitise the data. Because climate change issues were unknown to many of the government officials, it took much time and effort to explain and convince them about the necessity of the project and its social relevancy at national as well as international level. There co-operation was needed to get information on and access to existing data. In many cases, this was successful. Box 2.5 presents some more details on the data collection phase.

Box 2.5 Data collection for integrated coastal zone management.

Prior to the CSCCS, necessary data for assessing the vulnerability of the coast were scattered all over, not only over the various governments departments and Ministries, but also among the various NGO's and Consultancies within the country. It was therefore a huge and difficult task to collect all these data, which, taken the given time and financial limitations, may be regarded as a successful event. The process of data collection led to many questions dealing with methods of data collection, rehabilitation of the old observation networks, establishing new observation networks, data processing and establishment of a central database. Data were collected on the following four categories of sectors: (1) Ecology, (2) Geomorphology, (3) Socio-Economy and (4) Water Resources. From these four groups, the sector Ecology provided most data, followed by Geomorphology, Water Resources and Socio-Economy. The following sources for the data collection were used: (a) existing publications, (b) unpublished data collections, (c) maps, (d) verifiable indications and experiences of local people and experts. Despite of all these efforts large parts of the study area remained as a white spot, among others, due to the inaccessibility of the area. Necessary information about these areas was then derived from the satellite images or from the interpolations and expert judgments. However, more and precise information about the sectors mentioned above remained a (pre)requisite until the project end. Notwithstanding these shortcomings and gaps, the data collection gave, after its validation, a reasonable and well accepted representation of the coastal profile, on which bases the vulnerability has been determined. All the stakeholders, including the Government, scientists and the NGO's, now stress the importance of a Database Centre.

Because of the limited time to finish the project and the problems of access to data in the early stages of the project, it was necessary to use mathematical interpolation methods to fill the data gaps. This was especially the case with hydrological data, including water levels and salt-water intrusion. For other sectors as geomorphology, ecology, and socio-economy, this was not possible. Some data was derived from the stakeholders meetings and sessions with third parties. Besides expert judgment (using similarities of more or less identical cases in the region or neighbouring countries) information from local experts and individuals was used to complete the socio-economic picture. Field trips and awareness meetings also contributed to this. Gaps were filled by indirect interpretation of the available data. In some cases, expert judgment was applied. This was especially the case with determination of the hydraulic conditions zones (the exceedence frequency curve) and the protection sections of individual areas in the coastal zone. The lack of topographic data and detail information about the existing infrastructure, which were the main bottlenecks for determination of these zones, were solved by interpretation of vegetation maps, soil maps, knowledge from the local people, scientists involved in these areas and expert judgment. These data were mapped carefully through application of the GIS.

GIS analysis results provided the necessary information for the Flooding and Flood Risk model. Calculations were made for (1) the present situation en (2) the future conditions. Both cases were subdivided in (a) SLR = 0 m and no development and (b) SLR=1 m and development. Of these two cases the scenario (b) became a difficult task to solve. This is particular the case with the determination of the future developments of the various natural and socio economic systems and land-use categories within the coastal zone. Since adequate future planning and the necessary guidelines were missing for the determination of the future developments, it became quite difficult for the team leaders to value these developments in the future and the impacts of their interrelations. Of particular important were the assessments of the socio-economic developments, which basically are determined by the government in power. However, careful analysis of the present coastal profiles and intensive brainstorming processes with consideration of the possible climate change, has resulted in an acceptable outlook of the future development scenario.

In the course of the project, a few training sessions and training workshops were organised to make the local experts acquainted with this matter and to raise the awareness. Experts made available by the Dutch counterpart conducted the sessions.

The first problem rose when setting the boundary conditions of the study area. There existed no detailed topographical maps for the coastal area, except for parts of the districts Paramaribo, Wanica, Nickerie and of the east-west road connection along the coastal line. The lack of data made it difficult to determine the southern border of the area. From hydraulic and hydrological point of view, the southern border of the study area should be fixed based on the tidal effects, which under these circumstances reach up to the first rapids (waterfalls) in the main rivers of Suriname. Hence, the southern border of the research area was finally agreed near the first rapids/waterfalls in the main rivers. For the remaining area it was decided, that the contour lines necessary for the flood risk assessment, were to be derived from soil maps and vegetation maps.

With regard to the future development (projections) in the country, only the 'long term development plan' published by the Planning Bureau existed. It was assumed, that the overall population growth would be minimal, about 1.2% per year, and that Paramaribo, the capital of Suriname, would expand the most, about 3%. In addition, the economical activities and infrastructure would grow with the expansion of the capital and its suburbs. Furthermore, it was assumed that some grass swamps and mangrove forests will be converted into rice fields and aqua culture. Banana plantations were assumed to remain unchanged. Box 2.6 presents a storyline on the importance of mangrove forests for Suriname.

In reality the general development trends in the coming (30) years will highly depend on amongst others government regulations. The policy of the government of Suriname is directed towards the development of industries. Main emphasis in these developments will be made on bauxite, crude oil, and gold production. Development of the agricultural sector will need large investments, whilst other sectors as the horticulture would need to be reorganised substantially.

Box 2.6 Importance of mangrove forests.

Large part of the Suriname coast is occupied with mangrove forests. These forests are important natural ecosystems in the coastal zone and provide a natural defence system of the coastal line. During the last decades erosion at certain locations along the coast, especially in the districts Coronie (site 'Totness') and Wanica (site *Weg naar Zee*), has increased and has taken dramatic forms. From the study it appears that at the higher sea levels and changing wind patterns (wind velocity and direction) the level of erosion will increase further and losses will increase drastically. These two locations are typical examples of sites where the mangrove forests have been cleared for agriculture purposes and settlements and infrastructure were established. This has led to adverse changes in the sedimentation pattern in the coastal zone. To be able to understand the complexity of the coastal dynamics an in depth and detail study of the coast, and in particular the mentioned sites, is needed. The government of Suriname is highly interested in the defence of the coastal zone, since the ongoing and persistent erosion along the coastal zone causes huge damage to the natural ecosystems as well as to the local infrastructure and settlements on an annual basis. Hence, it wants use the preliminary outcomes of the study as inputs for their policy regarding the coastal protection and coastal zone management.

Erosion and sedimentation processes at the coastal line are, among others, determined by sediment transportation from the Amazon region. How the global climate change will affect this phenomenon is unclear. Moreover, changes in the sea current pattern are unknown. It was assumed that no changes in sedimentation transportation will occur and that (mud) bank formation will continue on higher sea levels. Furthermore, it was also assumed that waves, due to change in wind patterns, and oceanic current regimes will become stronger and accretion will continue. However, this will lead to increased erosion.

The natural defences as mangrove and shell cheniers are likely to protect the coast, except for those areas where intense erosion has destroyed them. Here tidal waters will penetrate into freshwater swamps and coastal aquifers. It was assessed that the mangroves retain landward and occupy the extended saline inter tidal area under SLR. Moreover, with the increase of seawater levels engineering structures at district Nickerie and Coronie can be expected to be less effective in their function to prevent flooding. The combined effect of all these factors will seriously affect amongst others the harbour facilities in the country. Consistent with existing climate data of the area for the past hundred years and GCMs, the study also assumed a decrease in precipitation in the future and thus the freshwater resources.

On the basis of the above mentioned assumptions, e.g. gradually increase of sea level rise, conversion of mangrove into agriculture land, ongoing mining of shell and sands in the coastal area, expansion of urban area and other infrastructure related to e.g. oil-extraction, pollution of coastal waters by municipal and agricultural lands, it was found that the coastal ecosystems are highly vulnerable to future developments and to climate change. Under these circumstances, it was assessed that the country will suffer large-scale losses of goods and services of the estuarine zone, which also function as the buffer zone for salt-water intrusion, sedimentation, wave attacks, etc. To preserve these ecosystems the number of protected areas need to increase and the total area covered needs to be enlarged.

The results of the project Country Study Climate Change Suriname showed the vulnerable state of the coast. This (a) raised the awareness of the stakeholders and (b) urged the government to take actions against the increasing effects of the sea level rise. The Suriname coast is, except for 7 km out of the 386, not protected from the attacks of the sea. Change in the climate patterns, e.g. wind speed and wind direction are, together with sea level rise and other developments in the coastal area, form a great threat for the existence of the natural and socio-economic systems in the coast. Moreover, the government is at present not able to cope with these challenges and problems, and consequently flooding, erosion and salinity intrusion are expected keep pace with climate change. There is a need for Integrated Coastal Zone Management (ICZM) in Suriname. ICZM is also a powerful tool for raising awareness. The study identified several short term, medium and long term actions that could be taken.

The short-term actions include:

- Start with an awareness program (radio, television, and newspapers);
- Establish a data base for wider use by stakeholders (national and international);
- Organise regional workshop;
- Develop and incorporate training in curriculum of the university program;
- Exchange of knowledge through missions by experts from countries with similar problems and from countries having experience in this field.

Medium- and long-term actions include the establishment of a Coastal Zone Management Authority with the following objectives:

- Enhance the understanding of the mechanisms of land and sea interactions in the coastal area. Develop and establishing information systems in the coastal area for solving possible resource conflicts;
- Develop and set up of an ICZM plan including coordination and management of the coastal zone. This could be done through training of local staff and through development of ICZM tools and concepts;
- Strengthen and establish co-operation between Suriname and neighbouring countries and between Suriname and the Netherlands;
- Establish a portal system.

2.11.3 Experiences and lessons learned

The Country Study Climate Change Suriname included a relatively considerable quantity of human resources and materials of institutions and government departments, including the University of Suriname. The study contributed to an increase in the scientific and technical capacity within these organizations.

The realization (execution) of the study had a rapid learning process, which implied ‘learning by doing’. Much information was known to exist, though widely scattered, at the government institutions and departments. The study benefited from guidance by Dutch specialists, consultants and experts, which have fostered human resources and technical capacity in the country to a significant degree. National specialists can now perform follow-up studies with less technical support from international experts

Furthermore, the study also speeded up the establishment of the present National Institute for Environmental Issues in Suriname (NIMOS) where also other Conventions are managed. In the course of the project implementation scientists from different disciplines worked together to produce the desired results, which are published in various papers, reports and maps.

This process proved, that national scientists were able to consolidate and endure multidisciplinary workgroups that can develop knowledge and reproduce activities. Hence, the project delivered a new generation of planners and analysts. The new generation of scientists has learned to recognise and understand the complexity of the coast in the perspective of the climate change, identify problems and where possible offers proper options for their solutions.

Box 2.7 Disruption of the drainage systems in the coastal area.

The low and flat coastal area of Suriname form the most fertile zone of the country, and hence provide necessary conditions for large scale agriculture practice, residence and for other industrial developments in the area. One common condition required for all activities in the area is adequate drainage. Drainage of this area has been taken place naturally, through rivers creeks and wetlands, and artificially, through sluices and culverts. In general drainage of the country is based on gravity flow, however as the sea level rises drainage of the agriculture lands, rural and urban areas will be stagnated and the threat of inundation, combined with heavy rainfalls, are observed more frequently. Moreover due to the maintenance in arrears of the hydraulic constructions (sluices, weirs, dams, culverts, etc.) saltwater intrusion takes place continually, resulting in shrinking of freshwater resources in the coastal area, and in particular, in the rural areas. In the urban areas, in particular Paramaribo, the problem of inundation is combated by installing additional hydraulic pumps. These developments in the drainage systems are thanks to the CSCCS project which for the first time mapped the vulnerability of these areas to global climate change.

An important and time-consuming factor following from the lack of knowledge on climate change issues were the divergent views offered by the participants on subjects as scale of inundation of the coastal area, coastal processes as erosion and sedimentation under future conditions, possible future socio-economic developments. This often resulted in long discussions, and unwillingness to accept each other’s view. Many of these views and proposals were based on difficult to verify or even insufficient data. Paucity of law and regulations also formed a burden in the execution of the study. Although the political situation was stable during the study implementation phase, it was difficult to calculate the development of the future socio-economical processes due to the lack of strong political impulses.

The lack of experience in this field and the huge amount of data that had to be compiled in this phase and the short time frame, especially the production of the thematic maps, placed a heavy burden on the project. Moreover, this particular study was for many scientists new and therefore it was difficult to assess the impacts of Sea Level Rise (SLR) over a period of hundred years (in 2100), especially on the development of socio-economic scenarios until 2100. These conditions were simplified by assuming the 1 (one) meter sea level to rise not within 100 years, but within 30 years (the year 2025). This assumption brought a lot of clarification for many of the participants, but was again confusing for others. These confusions and improper understanding of the conditions of the project led to many revisions of, amongst others, maps needed for the assessment and particularly on the economic values of different land use categories. Many land use categories such as swamps, lagoons, ponds, grass swamps and mangrove forests, were valued for the first time in this study. Since there was a lack of necessary expertise and information, proper evaluation of these land use categories was difficult and caused lengthy discussions on their economical value. In most cases, the valuations were finally based on expert judgment. According to some experts, these values were estimated at the low side.

The scheduled pilot project, that was supposed to train the local staff on the job, could not be executed due to financial and time constraints. The used financial support system of the project caused a number of problems during execution of the project.

Other lessons drawn from this study are:

- Many stakeholders were unable to consider a timeframe for the study of 100 years. It became clear that for studies to appeal and be relevant to policy makers and the public shorter timeframes needed to be assessed;
- Results of and recommendations from the study were in some cases misquoted by users. Recommendations were taken as assignments and not as guidelines towards the mitigation of the severe impacts of the sea level rise. This showed the importance of comprehensive reporting of results;
- More and frequent dissemination of information should take place, especially outreach activities are considered important;
- Many people are unaware of the major consequences and losses of due to climate change despite of the fact that a survey showed that they had observed negative changes in their environmental and economic conditions. An intensive awareness program was missing in the project. Awareness was only created in a relatively small stakeholder group;
- Adequate data was lacking, which delayed the study and forced the researchers to make numerous assumptions;
- The study also showed that the country Suriname is not ready, nor is it able with its existing abilities (expertise, technology, and financial means) to cope with the problems of SLR. Foreign support is needed for the country to cope with SLR and design and implement integrated coastal zone management. Furthermore, the rights and tasks of individuals and public agencies are not clearly specified leading to possible conflicting situations under the current legislation and regulations. In certain areas within the coastal zone several different stakeholders practice their economical activities, which in most cases are not regulated. Here, the current regulations are obsolete or missing and need to be adapted or elaborated. A recent example was the drainage of polluted water from the agriculture lands into the coastal wetlands, affecting the unique ecosystem negatively. Other economical activities as oil exploration in the coastal area intervene not only the proper functioning of the ecosystems, but also affect other small-scale economical activities as beekeeping, swamp fishery, hunting, etc., which may cause conflict situations among the stakeholders;
- With SLR the poor are most likely to be suffering the most from the inundation, flooding and from other negative impacts of the SLR, as salinisation and loss of land;
- No assessment has been done on the poor, from observations, especially in district Coronie, it follows that many of the inhabitants live in the old abandoned plantations, close to the Ocean. In the other districts as Commewijne and Nickerie this is also common. These people are not able to protect themselves from the threat coming from the Ocean. In contrast, the people living in the north of Paramaribo, also bordering to the Ocean, are more prosperous and therefore less vulnerable.

The vulnerability was evaluated by calculating the probability of extreme hydrological events of a certain intensity (e. g. inundation level and duration) in combination with 1 m sea level rise. It was quantified in terms of potential damage to persons or objects ('elements at loss and or at risk') in the regions at risk. By producing risk maps, using Geographic Information Systems (GIS) and surveys of vulnerability and hazard maps, areas were identified vulnerable to sea level rise. These maps indicated areas where urgent need for action improving the natural coastal defence systems. Much time was spent in discussing issues from different professional views. This process has proved to be needed to reach consensus among the stakeholders.

The next step was to interpret the V&A assessment for each sector and to review existing policies. This step of the study was even more difficult, because such policies were not clear and partly lacking.

The IPCC seven steps methodology proved beneficial for determination of the vulnerability of the coast, however, the timeframe for implementing the different steps was too short. Moreover, the relevancy of each step needed to be additionally underlined and explained by the experts.

Adaptation measures are not fully worked out in the study. This is simply due to the lack of required data. There is need to cover gaps in data and data management in the country. This highlighted the need for the establishment of a data bank, which should provide a useful basis for determining adaptation options, and regional coordination, especially regarding satellite images, rainfall data and migration problems. Establishment of data collection network is required, together with appropriate observations and data gathering techniques, and quality control. Baseline data analysis should also be included, where national and regional experts are involved.

The use of more local knowledge across the entire country should is considered necessary. Training should be enhanced and more means should be freed for these purposes.

Use of methodologies

As mentioned before, the IPCC seven steps method was used to determine the vulnerability of the coast. The Dutch consultants explained method in one workshop session for the national project managers, team members and technicians. The local team decided to use data, derived from the existing studies, maps and reports. These data were mainly spots and studies on local scale, which were often limited to a single item or sector.

An overall picture of the coast was not available. Therefore, satellite images and other data were purchased, out of which necessary maps were produced for sediment, soil, catchments, vegetation, population, geology and rainfall. The respective consultants and scientists working at the project needed to update these maps, because for some areas no recent satellite pictures were available. Additional data for updating these maps were received from various sources, e.g. from government departments, consultant's bureaus, institutions, NGO's, and individuals. In many cases, data was created by simple assumptions or interpolation of some events to fill the necessary data gap. It was for the first time that huge data sets were presented in integral manner and using GIS. Investment in creating data and training of personnel in using GIS, and in other applications was essential for obtaining success in the project.

2.11.4 Follow-up research

Before closure of the CSCCS project in 2000, Suriname started with another project with the help of UNDP-GEF, aiming to produce Suriname's first national communications to the UNFCCC. It was agreed, that the national communication would use the results of the country study as basis for the National Communication. However the National Communication is not finished yet.

In the recommendations of the study, it was proposed to give the project a follow up, but the economic situation of the country prohibited the execution of even part of the recommendations. The donor of the first NCCSAP project financed a follow up project, that started in July 2003 under the responsibility of the Ministry of Labour, Technology and Environment. The project will focus on the area of adaptation with specific emphasis on linkages between poverty and climate change.

2.11.5 Policy implications

With the signing of the Protocol the government of Suriname not only committed itself to report to the UNFCCC, but also to undertake within its possibilities the necessary steps to 'cope with and adapt to potential climate change and sea level rise, including the development of globally acceptable methodologies for coastal vulnerability assessment, modelling and response strategies'.

Due to amongst others political priorities, the change of government, and the financial situation of the country the findings and recommendations of the study were not published until 2003. Box 2.8 presents some highlights of the effects of the recommendations from the study.

Box 2.8 Effect of the recommendations for society, including the policy makers.

The study clearly showed that Suriname's vulnerability to climate change can be ranked amongst those of the small island states. These results shocked the society, including the government, seriously. Many of the inhabitants were not aware of the ongoing problems in the coastal area and the need of a better management of the resources. With the publication of these results a milestone had been reached, which contributed to many different sectors and policies in the country, including the preparation of coastal zone management plans for the northern parts of the districts bordering the sea, preparation of 'discussion paper on marine and coastal management for the development of a framework policy and strategic plan for sustainable management urged by the Government, new proposals on CZM with emphasis on detail study of physical process at the coastal line. In addition, governmental officials (e.g. ministers) are using the concluded results to put forward their policies regarding the protection and sustaining the development of the coast.

The choice of the study was made as the result of consultations with the ministry of planning (national planning office) whilst the project was monitored by this ministry through one member in the project steering committee. The project members kept their respective ministers informed of the progress of the project and the problems in the field.

The committee took the feedback from the stakeholders into account. The results from the study were used in a long term planning of the sea defence in the northwestern part of the country. To protect the capital investment, in the low-lying rice area of the Nickerie district the height of the sea fence was increased in line with the expected sea level rise and the feasibility of the adaptation.

Paramaribo with a population of about 200.000 inhabitants lies less than 15 km from the coast. The present drainage system, which is based on gravity, is becoming ineffective. SLR will worsen the situation. To adapt the situation, 'a Master plan study urban drainage greater Paramaribo' has been set up, indicating the need of installing necessary pumps and means for artificial drainage.

Many governmental departments took advantage from the training and dissemination activities and the application of the Geographic Information System. The project was particularly to the advantage of the Department of Natural Resources and Environmental Assessment (NARENA) of the University of Suriname as they have broadened their know-how and capabilities, among others on analysing and processing satellite images. Hence, the NCCSAP studies have impacted various disciplines in the country and promoted the use and the application of GIS information on a broader scale.

2.11.6 Conclusions

Notwithstanding the complexity of the earlier mentioned discussions and barriers in executing the project, it is possible to draw some principal conclusions and features, which are central to this project. These are:

- The use of the seven steps in determining the vulnerability of the coast has had good results. The methodology was sufficiently flexible to meet most of the needs;
- A wide variety of techniques and know how was gained in assessing the impacts of climate change during the execution of the project. It can be concluded that the transfer of knowledge was successful;
- The need of an integrated coastal zone management became obvious and necessary to halt certain negative processes and affect the ongoing development in a positive way;
- The need for continuation and further study of the coastal vulnerability was highlighted, including the need for co-ordination of the different activities in the coastal sectors and the policies of the different government departments concerned;
- The project can also be regarded as a strong awareness and education program to the nation, since this was the first attempt in determining the indirect impacts of climate change for Suriname;
- In this regard some strategies for mitigating the impacts of the sea level rise have been proposed;
- Furthermore, a database has been setup, which may also be regarded as an important result;
- Implementation will be not an easy task. Stakeholders and agencies must co-ordinate and harmonise their policies and programs. Policymakers should have the political will to put the measures in place and provide the necessary resources.

Main product

Country Study Team Climate Change (1999). *Country Study Climate Change Suriname and First Steps towards Integrated Coastal Zone Management*. 83 pp with 8 Technical Reports: Geomorphology. Profile 29 pp (P.C. Dixit), Geomorphology. Prediction. 12 pp (P.C. Dixit), Socio-economics. Profile 24 pp (Consen, J.R., R. Sanchit & J. Tawjoeram), Socio-economics. Prediction 29 pp (Consen, J.R., R. Sanchit & J. Tawjoeram),
Ecology. Profile 28 pp (Baal, F, M. Hiwat & F. van der Lugt), Ecology. Prediction 23 pp (Baal, F, M. Hiwat & F. van der Lugt),
Water Resources. Profile 77 pp (Amatali, M & S. Naipal), Water Resources. Prediction. 24 pp + Appendix (5 pp). (Amatali, M & S. Naipal),
Flood and Flood Risk Modelling (Hoozemans, F.M.J.),
Geographic Information System (Van Veldhuizen, H.), GHG Inventory 1994. 108 pp (Becker, C., H. Breinburg, H. Mac Donald, M. Playfair & H. Ramdihansing),
Final report 1999 (Amatali, Becker, Hoozemans, Leenen, Naipal, Veldhuizen).

2.12 Vietnam

Nguyen Ngoc Huan[29]

2.12.1 Introduction

Vietnam is a country with a characteristic coastline length of 3,822 km (excluding islands) that runs from Mong Cai in the north to Ha Tien in the south. Vietnam has a long coastline and a narrow hinterland. Flooding in the coastal zone is mainly a result of high river discharges, elevated sea level during typhoons and weak dykes.

Vietnam is a signatory to the UNFCCC and is making preparations to meet its commitments. A global inventory made in preparation of UNCED in Rio de Janeiro, showed that Vietnam is one of the most vulnerable nations as regards the threat imposed by climate change, including sea level rise (SLR). It was clearly recognised that the vulnerability needs to be quantified and response strategies need to be developed. Vietnam was thus chosen to conduct three pilot studies on the impacts of climate change on the coastal zone.

These studies titled ‘Vietnam Coastal Zone Vulnerability Assessment and First Steps towards Integrated Coastal Zone Management (Vietnam VA Project)’ were conducted in Vietnam from November 1994 till April 1996. The aim of the VVA- Project was to assess the vulnerability of the whole coastal zone of Vietnam to increased sea level rise and related effects due to climate change. The first pilot study was a study on dyke erosion in Nam Ha Province (in July 1995), the second one was a study on flooding and lagoon management in ThuaThien Hue Province (in November 1995) and the third one was a study on planning in Vung Tau (in March 1996). The choice for the sectors was determined by their economic importance for the country as well as by the existing expertise in the country. The study areas are shown in Figure 2.13.

[29] Centre for Application of Hydrometeorological Technology (HYMETEC) under the National Hydrometeorological Service of Vietnam belonging to the Ministry of Natural Resources and Environment, hmec@fpt.vn

In addition to the development of different national climate change scenarios, many studies have been developed such as the studies on the recent historical setting, political developments, population, employment, subsistence farming, land use, economic growth, institutional arrangements for coastal zone management, etc.

The 1996 coastal zone VA study assessed the impacts of various scenarios for sea level rise - namely coastal erosion and inundation - on all the coastline with rough estimations of population, land value and natural habitats and species at risk as well as an evaluation of the cost of adaptation, mainly protection. Within this content, the main objective of this pre-NCCSAP study on the impacts of climate change on Vietnam Coastline was to express a more comprehensive and integrated view of coastal vulnerability to climate change.

Assisted by UN Agency UNITAR with a training project (CCTRAIN), the Government of Vietnam has set up a 'Country Team' comprising representatives from key Ministries and operates via a Coordinator, Executives, a Core Team and 4 Working Groups. The Hydrometeorological Service (HMS) is focal point in Vietnam for Climate Change issues and a leading member of Country Team providing the Core Team Secretariat and with the Director General of HMS as Coordinator and Chairman.

In addition to other activities initiated be the Country Team and recognising the potential risks and the need to respond to the impacts of sea level rise on the Vietnam coastal zone and its sustainable development, a specific request for assistance with '... *a study on vulnerability assessment along the guidelines as set up by the coastal zone management subgroup of IPCC*' was made by the Director General of HMS to the Netherlands Embassy in Bangkok.

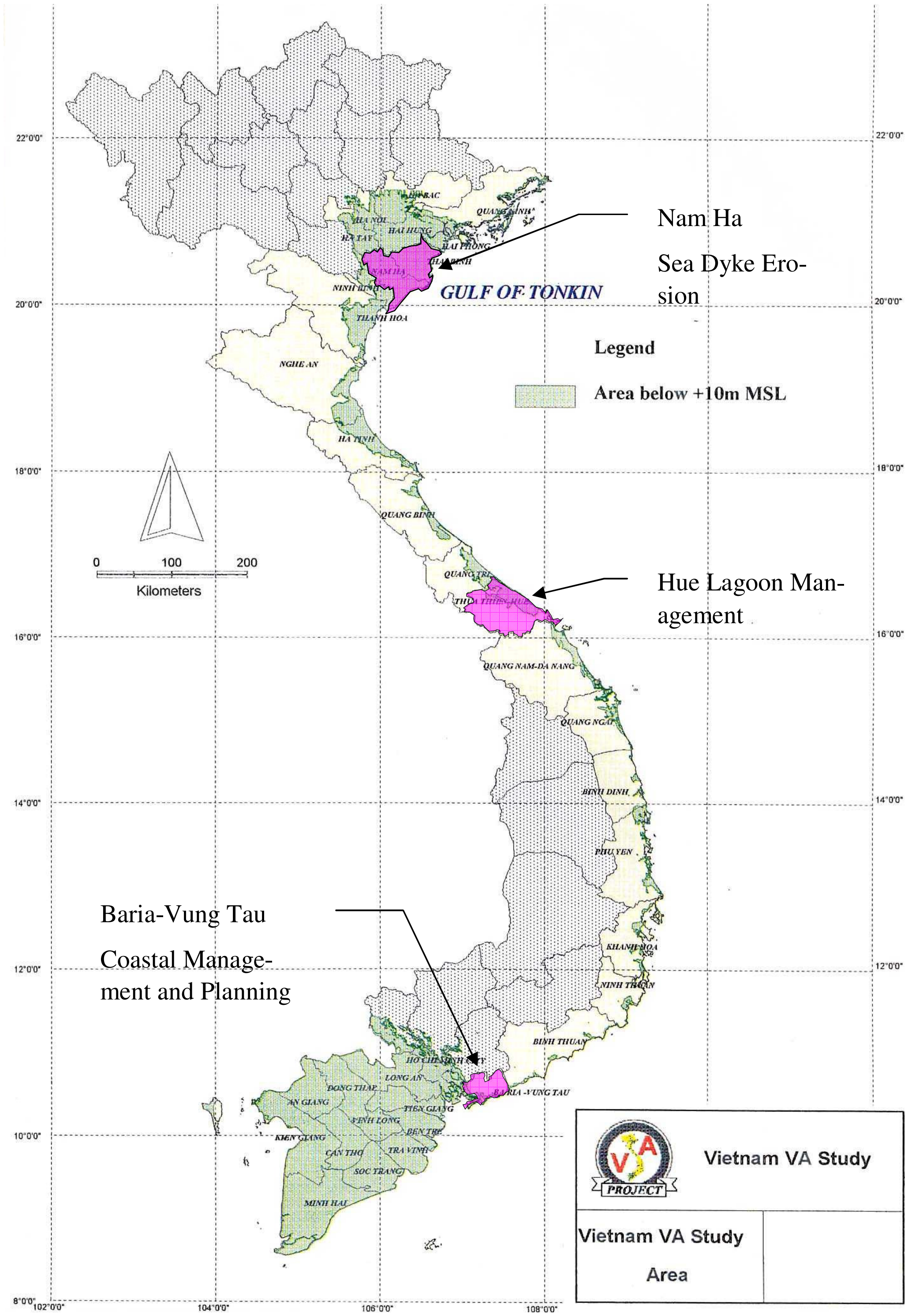

Figure 2.13 The three study areas in Vietnam.

Subsequent meetings and discussions both in the Netherlands and Vietnam culminated in a Pilot Mission to Vietnam by coastal specialists from Poland and the Netherlands in October 1993. As a result of this Pilot Mission an outline for an 18 month study in Vietnam was identified with the primary objective to provide the Vietnamese counterpart with assistance in executing a VA to assess the impacts of sea level rise on the coastal zone of Vietnam and by doing so strengthening the capacity of Vietnamese organizations to setup integrated coastal zone management. The project was initiated in November 1994.

2.12.2 Approach

Based on the results and experiences of the 1996 VA study, it was decided to include the following improvements in the NCCSAP funded study:

1. Consider case studies that are representative of the main coastal environments. Three geographic locations were chosen: the *Nam Ha Province*, Hai Hau District, where serious erosion of weak dyke defences are present; the *Hue* in the central country where a coastal lagoon system is present, and the *Vung Tau*, where it is possible to take advantage of natural deep water port facilities and a burgeoning nearby the off-shore petroleum industry and where good recreational beaches and tourism are present;
2. Use a multidisciplinary approach by building a team constituted of personnel from Department of Dyke Management and Flood Control (of the Ministry of Agriculture and Rural Development - MARD; in the study on sea dyke erosion in Nam Ha province), personnel from the local Hue University, the Hanoi University and the Sub-Institute of Physics (Ho Chi Minh city; in the study on flooding and lagoon management in Thua Thien Hue province) and local authorities or local specialists were consulted and informed (in the study on Vung Tau Planning);
3. For each case study, consider not only the impacts of sea level rise buts also other potential climate change impacts such as changes in rainfall, temperature and up-welling;
4. Perform a more comprehensive assessment of socio-economic impacts by using socio- economic scenarios and discount rates;
5. Have a broader approach of adaptation to enlarge the basic solutions developed by the IPCC/CZMS: retreat, accommodate, protect (IPCC/CZMS, 1990).

The study used a mix of methodologies such as Geographic Information System (GIS) analysis to determine the areas flooded for four different scenarios with flooding: 1 per year, 1 per 10year, 1 per 100 year and 1 per 1000 year by using a SPANS EXPLORER software packet. Flooding and Flood Risk (FFR) analysis combined the results from GIS analysis and the Geomanagement System (GMS) analysis, a data management system designed by Da Vinci Consultants in Belgium.

2.12.3 Results of the coastal zone study

The three case study areas are described in more detailed in this section. Afterwards, the main results of the VA study are presented.

Area 1: Sea dyke erosion in the Nam Ha province

This study area was limited by the Red River Delta coastal provinces of Thai Binh and Nam Ha, but the study focused on the serious erosion of weak sea defences in the Hai Hau district, Nam Ha province.

Site visits were undertaken together with personnel from the Department of Dyke Management and Flood Control (of the Ministry of Agriculture and Rural Development-MARD) and in liaison with local authorities at Provincial, District and Commune level.

It became clear that the shoreline and foreshore (several kilometres seaward of shoreline) were facing a serious sand depletion problem, unlike the majority of the Red River Delta coast that is accreting. Serious erosion of about 30 m/year is being experienced at the shoreline of the Hai Hau district. Former lines of sea defence were overtaken by the retreating coastline and are visible 200 m offshore of the present dyked coast. The study area has 8 mangrove species, 38 mollusk species, 30 crustacean species and 40 bird species. Economic activities related to the coastal zone include agriculture, aquaculture and fishery. The area has a high potential for aqua-culture in the Red river delta - one of most developed regions of whole country.

Area 2: The Thua Thien Hue Province

This study reviewed the problem of flooding and management in the coastal lagoon system at Hue in the central coast province of Thua Thien Hue. It was conducted in November 1995. Site visits were undertaken together with personnel from local Hue University, Hanoi University and the Sub-Institute of Physics (Ho Chi Minh city). Extensive discussions and meetings were held with local authorities, particularly with the People's Committee of Thua Thien Hue Province in the City of Hue.

The City of Hue has as major assets its cultural history (seat of power of the last emperor of Vietnam- Nguyen Dynasty), its extensive lagoon system (Tam Giang to Cau Hai Lagoon), its arable land, fresh water supplies and tourism resorts. In addition, aquaculture, port development and transportation are adding to the prosperity of the Thua Thien Hue Province. However, serious threats jeopardise these assets, such as frequent (almost annual) extensive flooding from the 3000 mm of rainfall which falls each year in the period September to November and can be accompanied be strong typhoons with storm surges. Salinity control problems threaten rice production (threatened by high salinity) and aquaculture (threatened by low salinity). Port development is hampered by sedimentation problems in some areas and erosion in others. Water levels will be affected but also salinity impacts and morphological changes can take place with huge consequences.

The study reviewed the physical, environmental, economic and institutional properties and constraints of the region and set out a framework for addressing the complex issues in more detail.

Area 3: Vung Tau

This study reviewed the planning issues presently facing the area of Vung Tau in the south of Vietnam. It is well placed to provide both deeper port access for import of goods into the region (Ho Chi Minh City - Song Be - Vung Tau = 'Southern Focal Economic Zone') and to attract tourists to its sandy beaches. The region is almost completely flood free due to the absence of typhoons, which pass far north of Vung Tau, and the wetland ecosystems in its wide river mouths which prevent high flood levels near the coast.

In contrast, one of the largest remaining natural mangrove forests in Vietnam is endangered by port developments. The mangrove forest is not only an environmental resource but it also plays an important protective role to the local river trading ports and waterways leading to the Port of Saigon. Pollution due to port development, management and protection of the beaches and dunes, tourism development in the coastal zone and industrial development of petrochemical industry are all major issues that pose threats to the assets of the region.

An important inventory and visualisation of the key issues was achieved which provides focus for careful consideration of planning and development options and a framework for further study.

Main biophysical impacts

Areas at risk

Generally, the sea and estuary dykes are under-designed for the natural forces and processes. This results in high maintenance requirements or the acceptance of high damage and land loss. The highest costs for annual maintenance are incurred in Nam Ha (Area 1), where serious annual erosion and over topping of sea dykes regularly takes place. Table 2.18 presents an overview of the main impacts in the three areas investigated.

Table 2.18 Area lost and area at risk in the case study areas in case of 1 m sea level rise.

	Unit	Coastal region		
		Nam Ha (Area 1)	TT - Hue (Area 2)	Vung Tau (Area 3)
ASLS0 (no sea level rise)				
Area lost	Km^2	0	0	0
Area at risk	Km^2	1	1	9

Threats to wetland forests

The present wetland forest area is only 30% of the wetland area in 1940. The creation of fish ponds was not only bad for the environment but it was also carried ineffectively, resulting in the acidification of the ponds leading to low efficiencies and abandonment. In general, the tidal marshes area ecologically vital as they provide the spawning and nursery grounds for numerous bird, fish, prawns and mollusk species. A typical example is the Xuan Thuy reserve area at the mouth of Red River (Area 1).

Threats to coastal biodiversity

In general, the biodiversity in Vietnam is rapidly decreasing. This topic is of such national concern that Vietnamese scientists have recently published the Sach Do Viet Nam (*Vietnamese Red Book),* summarising the status of threatened animals in the country. Table 2.19 present the status of the major groups in term of endangered, vulnerable, threatened, rare or undetermined species.

Table 2.19 Status of the major groups in term of endangered, vulnerable, threatened, rare or undetermined species.

	Inverts	Fishes	Reptiles	Birds	Mammals	Total
Endangered	10	6	8	14	30	68
Vulnerable	24	24	19	6	23	96
Threatened	9	13	16	32	1	71
Rare	29	29	11	31	24	124
Undetermined	3	3				6
Total species in danger	75	75	54	83	78	365
Total species in the country	7000	2500	260	800	275	10835

Source : Vietnamese Red Book (Red Book Categories of Vietnam).

Another threat is the destruction and degradation of coastal vegetation and coral reefs by human activities as marine tourism, port operations, oil and gas winning. These activities lead to coastline and dyke erosion and consequently to loss of critical shelters for fishermen. Serious losses to mangrove areas as mentioned are an additional threat.

Salinity intrusion

Salinity intrusion in the coastal zone is increasing due to fresh water extraction for irrigation and drinking water and due to dam construction in some catchments. Sea level rise will cause a higher penetration of saline water into rivers, creeks and streams as well as into groundwater systems.

Man-induced subsidence due to groundwater extraction in Vietnam

1. Red River Delta: The highest subsidence of 176 mm from 1988 to 1992 (about 4 cm/year) was found in the south of Hanoi near Phap Van, whilst an average subsidence rate of about 10 mm/year was be estimated for the greater Hanoi region. By 2010 the amount of groundwater exploited may increase to twice the present amount, while in 2020 a groundwater exploitation of about 1 million m^3/day is anticipated. Subsidence computations predict a total maximum subsidence of 750 mm near Phap Van under an exploitation rate of 1 million m^3/ day;
2. Central Coastal Areas: The cities of Vinh, Hue, Da Nang and Nha Trang all use surface water for meeting their water demands. Only in Da Nang, some groundwater is exploited on a small scale, while in Nha Trang wells are being used for pumping groundwater coming from rivers. Therefore, increased subsidence of these urban areas is negligible;
3. Ho Chi Minh City and Mekong Delta: Ho Chi Minh City and Vung Tau mainly use surface water for agricultural production and living conditions. Some wells are also being used for small ground water exploitation of about 30,000 to 50,000 m^3/day, which is about 10% of the city's demand. Groundwater reserves in the Mekong Delta are very large. But its potential use is limited by three factors: salinity, permeability of aquifers and salinity intrusion during aquifer recharge. The safe yield of the basin has been assessed at roughly 1 million m^3 per day. In general, the subsidence is not yet measurable, but it needs careful attention due to the area's sensitivity to the sea level.

Main socio-economic impacts

For each of the case studies, the population and the economic value at risk was assessed considering the different inundation and socio-economic scenarios. The main results are summarised in Table 2.20.

Table 2.20 Socio-economic impacts of inundation and costs of adaptation (n.k.=not known).

Impacts	Unit	Nam Ha	TT. Hue	Vung Tau
SLR0 (no sea level rise)				
Population to be moved 1995	Persons	0	0	0
Population at risk 1995	Persons	629	42020	3454
Population to be moved 2025	Persons	0	0	0
Population at risk 2025	Persons	885	57254	5420
Capital value at loss 1995	US$ mill.	0	0	998
Capital value at risk 1995	US$ mill.	0	15	305
SLR1 (sea level rise 1m)				
Population to be moved 1995	Persons	0	383605	58463
Population at risk 1995	Persons	8142	37462	955
Population to be moved 2025	Persons	0	522515	n.k.
Population at risk 2025	Persons	11432	51260	1571
Capital value at loss 1995	US$ mill.	0	135	998
Capital value at risk 1995	US$ mill.	6	12	15
Capital value at loss 2025	US$ mill	0	714	18626
Capital value at risk 2025	US$ mill.	50	78	305

Exchange rate 1 US$ = 15.500 VND (2003)

In terms of economic impacts, the main components at risk are private homes, agricultural and aqua-cultural production sites. Moreover, the impacts of climate change on aquaculture and fisheries will be determined by the reduction in resources as well as by an increase in extreme events and coastal erosion, which will affect infrastructure. This in turn could influence the price of fish with consequences on food security, in particular for the poorest, and loss of purchasing power.

Adaptation options

In the three case studies, information was extracted from the protection development plan drafted by the Vietnamese Government Ministry of Agriculture and Rural Development (Department for Dyke Management and Flood Control) to estimate the costs for upgrading Vietnam's coastal defence systems to achieve improved safety levels and improved quality of life. According to the plan, US$ 0.7 billion is necessary for improving sea, river and estuary dykes. Another US$ 5.8 billion is necessary for upgrading other defence measures such as raising houses and installing pumps. In the protection development plan, sea level rise was *not* taken into account. Hence the actual costs are likely to be significantly higher.

Upgrading of sea and estuary dykes

It is estimated that to improve safety levels to acceptable design standards a height increase of 1.5 to 2 m is required in the north, 1 to 1.5 m in the south and 0.3 to 1 m in the central provinces. A total of 2,700 km of sea and estuary dykes needs to be upgraded.

Upgrading and development of other measures

Raising lands (1800 ha; US$ 72.5 million), raising houses (1,3 million on 128,550 ha; US$ 3.7 billion) and pumping (700,000ha, unit costs ranging from US$ 700/ ha in the south to US$ 6000/ ha in the north) are the main measures to prevent the effects of flooding.

Beach nourishment

The proposed plans for beach nourishment cover only 14 km of coastline in tourist areas at a total cost of US$ 22 million (unit cost US$ 1.5 million/ km).

Groins

Existing groins are rock groins in the north and timber groins in the central provinces. A small length of coastline of no more than 50 km is nominated for groined protection at a total cost of US$ 14.3 million.

Conclusions

People, capital value and habitats in low-lying areas of Vietnam are presently very vulnerable to flooding. The impacts of climate change will further aggravate the pressing situation. There is a danger that the focus on rapid economic expansion and industrialization will absorb development funds needed to protect and sustain the agricultural yields necessary for Vietnam to feed its own population and meet export quotas. Appropriate measures require national and international co-operation.

The findings showed the high sensitivity of Vietnam to a rise in mean sea level could severely impact development and growth. Vietnam's vulnerability was ranked as critical and costs of full protection measures were seen to be immense. Most sensitive areas are the Mekong and Red River Delta, the Ho Chi Minh- Vung Tau area and the Hue- Da Nang area. It is expected that this study helped to improve the way of the decision maker and the public are informed on climate change issues.

However, this study also had its limitations. Due to an incomplete database, some models could not be used in the research and impacts of tourism were not considered in this study.

2.12.4 Experiences and lessons learned

The V&A study was practical and useful. This study project assessed the vulnerability of the entire coastal zone of Vietnam to the impacts of sea level rise due to global warming and outlined the first steps towards Integrated Coastal Zone Management (ICZM) in Vietnam. The pilot studies at three sites - Nam Ha, Hue and Vung Tau - were included to provide insight into the present coastal management problems.

The project was executed by a Vietnamese team working closely together with a European team comprised of Polish and Dutch experts in coastal zone management. During the study, extensive data on physical, socio-economic and institutional characteristics of the coastal zone of Vietnam were collected. Digital maps of the entire coastal zone formed the basis for GIS analyses, which determined areas of different land-use types inundated by various flood scenarios. Further analyses provided loss and risk figures for land use types, population and capital value. Future development trends as well as institutional, organisation and legislative arrangements for coastal zone management were also reviewed and implications analyzed. During the project, the Vietnamese team obtained many experiences in working by groups within a multidisciplinary team to survey and assess comprehensively the impacts on the coastal zone and their consequences as well as apply many different measures to adapt to the envisaged impacts.

2.12.5 Follow-up research

Vietnam urgently needs to increase its coping capacity associated with sea level rise. The present coastal defences are inadequate to ensure the necessity safety levels for sustainable growth in the coastal zone and increasing flooding, erosion and salinity intrusion will hamper development in the coastal zone.

Integrated Coastal Zone Management (ICZM) can be used to focus the needs and disperse the ideas, data and initiatives. It is proposed that a Coastal Zone Secretariat (CZS) should be established in Vietnam, operating within the framework of a proposed Strategy and Action Plan for ICZM. Main themes of long-term proposal are as follows:

- Dissemination and exchange of information;
- Harmonization of assessment and planning methodologies;
- Development and dissemination of decision support and planning tools;
- Training; conferences, workshops and seminars;
- Co-ordination of bilateral and multilateral development projects.

The plans drafted by Vietnamese Government Ministry of Agriculture and Rural Development address the upgrading of Vietnam's defences to achieve improved safety levels and improved quality of life. They do not take into account the effects of sea level rise. Total cost of upgrading described is summarised as US$ 0.7 billion for sea, river and estuary dykes and US$ 5.8 billion for upgrading of the defence measures (including raising houses, pumping etc.).

A joint funding agreement between the Vietnamese Government and the World Food Program has been set up for upgrading a total 815 km of sea and estuary dykes in two programs at cost of US$ 66 million of which US$ 38 million provided by WFP and the remainder from the Vietnamese Government. Additional funding from other NGO's (OXFAM, ICCO) is being implemented on a smaller scale (US$ 2.5 million). This still only deals with upgrading of 30% of total sea and estuary dyke system.

Policy implications

There were no detail policy measures that followed the VA study, except for the implementation strategy where coastal protection and management was proposed as a short-term option.

Vietnam has not enough funds to develop new adaptation study projects. It is considered that financial resources for further projects must mainly be funded from external sources, with the national budget being used for partial contribution or for other urgent needs.

Four principal policies are as follows:

1. Greenhouse mitigation
2. Adapting to climate change
3. Legislation and policy formulation
4. International networking

Some climate change policies are shown in Table 2.21.

Table 2.21 Principal Policies of the Vietnam Country program on the implementation of UN Framework Convention on Climate Change.

Policy
Rebuild agricultural plans for every region taking into account climate trends
Research/ implement new practices
Research climate change mitigation methods, production technologies
Apply international experience and technologies as appropriate
Build new reservoirs for hydropower plants
Improve drainage of low lying areas (more pumps)
Improve quality and protection of dykes, sea defences, estuary dykes etc.
Improve coastal protection by mangroves, beach defences etc.
Expand the hydrometeorologic station network
Improve forecasting and warnings (e.g. typhoon, flood warnings, etc)
Strengthen ability of flood and drought committee to cope with emergencies
Proclaim decrees and guidelines for climate change response
Enforce measures to deal with violations of climate change related provisions
Proclaim law on the exploitation and protection of forests, mangroves etc.

As mentioned above, there are some methodologies and studies such as GIS analysis, FFR analysis and GMS that are in line with policy needs. However, they concerned physical and environmental issues rather than institutional or socio-economic issues. The institutional, organizational and legislative issues should be more emphasised in future ICZM studies in Vietnam.

2.12.6 Conclusions

Legal, institutional and organizational aspects are at present a serious threat to good coastal zone management in Vietnam[30]. There is a lack of written legislation governing specifically activities and developments in the coastal zone. Many organizations can contribute to a better understanding of the coastal zone but coordination and communication is weak, duplication of efforts is often encountered and no clear framework of roles and responsibilities exists beyond the hierarchy structures of the present party and government system. There is a high degree of 'vertical' decision making with a low degree of consensus at lower authority levels. The staff is well motivated and has excellent organizational abilities. Working conditions and facilities are quite good.

[30] Since the conclusion of the studies described here, much has improved. See also Section 4.3.1.

Economic and financial aspects are the most serious of all problems. The present capital spent on coastal zone defences is far short of that required to meet objectives of improved safety levels, even without sea level rise. The danger of flooding is rapidly becoming an obstacle to development.

The enormous funding required, even for upgrading of coastal defences, even without sea level rise, is a very heavy burden on Vietnam. It is not at all feasible to expect that even the development plan for coastal zone flood prevention will be significantly carried out. This means that unsafe dyke level and frequent flooding problems will persist for at least several decades.

Important adaptation measures include the increase of pumping capacity and elevation of houses. Particularly in the Mekong Delta, raising houses is now the only feasible option. Increasing pumping and raising embankments to lengthen the summer crop season has been very successful but this has to be carefully managed to avoid serious upstream or downstream hydraulic and water quality problems.

Technical level of staff and facilities for ICZM studies is reasonable. Further training and experience is required to improve knowledge of coastal zone processes and coastal zone protection methods. Data availability is not a serious problem in the sense that a large amount of good CZM data exist but exchange of data and readiness for distribution is limited.

There is a danger that the focus on rapid economic expansion and industrialization will absorb development funds needed to protect and sustain the agricultural yields for Vietnam to feed its own population and meet export quotas.

In summary…Vietnam's overall vulnerability level to a 1m sea level rise over the next 100 years is *critical*! The VA project has been recognised and appreciated within Vietnam and constitutes a fertile contribution to further development.

Main products

Harris, F.R. (1994). *Vietnam Coastal Zone Vulnerability Assessment and First Steps Towards integrated Coastal zone Management* - Project Document (Uitvoeringsdocument), IBW-PAN, - Delft Hydraulics, The Netherlands, October 1994.

Vietnam Coastal Zone Vulnerability Assessment and First Steps Towards Integrated Coastal Zone Management (1995). *Report No. 1, Inception Report.*

Vietnam Coastal Zone Vulnerability Assessment and First Steps Towards Integrated Coastal Zone Management (1995). *Report No. 2, Data Collection.*

Vietnam Coastal Zone Vulnerability Assessment and First Steps Towards Integrated Coastal Zone Management (1995). *Report No. 3, Methodology Report.*

Vietnam Coastal Zone Vulnerability Assessment and First Steps Towards Integrated Coastal Zone Management (1995). *Report No. 4, Pilot Study – Sea Dyke Erosion in Nam Ha Province.*

Vietnam Coastal Zone Vulnerability Assessment and First Steps Towards Integrated Coastal Zone Management (1995). *Report No. 5, Pilot Study - Flooding and Lagoon Management, Thua Thien Hue Province.*

Vietnam Coastal Zone Vulnerability Assessment and First Steps Towards Integrated Coastal Zone Management (1996). *Report No. 6, Pilot Study – Coastal Management and Planning, Baria-Vung Tau Province*'.

2.13 Yemen

Mohamed Said El-Mashjary[31]

2.13.1 Introduction

Yemen signed the United Nations Framework Convention on Climate Change (UNFCCC) in 1992 during the Earth Summit in Rio de Janeiro. The parties participating to the Conference of the Parties were required to submit their Initial National Communication (INC) of their respective countries. In August 2003, the Yemeni Government through its cabinet approved the Protocol Kyoto and the necessary documents were sent to be deposited at the United Nations headquarters to be processed and approved.

Yemen received funds from the Government of the Netherlands through the National Climate Change Studies Assistance Program (NCCSAP), and from the Global Environment Facility (GEF). Climate change was a new subject in Yemen and consequently the capacities in this field are very limited. Capacity to assess topics on climate change, particularly the main focal areas of Green House Gases (GHG) inventories, mitigation analysis, and vulnerability and adaptation assessment remains restricted to a few research institutions.

In this section we focus on the results from the vulnerability and adaptation study in the agricultural sector as this sector is the economic mainstay in Yemen, contributing about 20% to its GDP. Cereals, mostly millet and wheat are grown in about 60% of the cultivated lands, but a large portion of the country's import bills is reserved for wheat, grain and flour. Agricultural production in Yemen depends primarily on farm natural resources that are vulnerable to climate change. The objective of this study was to identify and to evaluate possible adaptation measures that will enable the agriculture sector to cope with climate change.

2.13.2 Approach

The agriculture study team focused mainly on the effects elevated CO_2 concentrations and higher temperatures on the economic production and physiological mechanisms of wheat and potatoes in two main realms of Yemen. The Agriculture Research and Extension Authority (AREA) in Dhamar, Yemen developed the climatic database. Daily weather data were collected for assessing rainfall and temperature patterns and used for climate modelling. Detailed data were especially needed as rainfall patterns in semi arid conditions can best be analyzed using 10-day averages. A frequency analysis of the number of frost days requires daily data as the extremes are levelled out in 10-day or monthly averages. The rainfall data and number of frost days were used to predict potential yields of crops and to calculate amongst others irrigation schedules.

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Figure 2.14 Map of Yemen.

Four sites were chosen to represent the two main ecological zones where both wheat and potatoes are grown. The selected zones and sites were:

1. The mountain highland zone, study sites Dhamar and Ibb;
2. The desert plateau zone, study sites Marib and Seyoun.

The studied zones represent well-pronounced variations in rainfall and temperature. The highlands climate ranges from semi-arid (Dhamar) to sub-humid (Ibb); whereas, the plateau climate ranges from arid (Marib) to hyper-arid (Seyoun).

The UNEP/IVM handbook on Methods for Climate Change Impact Assessment and Adaptation Strategies (Feenstra *et al.*, 1998) and the IPCC Technical Guidelines for Assessing Climate Change Impacts and Adaptation (Carter *et al.*, 1994) were used as guidance in the vulnerability and adaptation assessment.

2.13.3 Results of the climatic change on agriculture in Yemen

The agriculture team used the semi quantitative methods including biophysical and socio-economic assessments. A model using Microsoft Excel was adopted to assess relevant effects. The FAO CROPWAT (Smith and Martin, 1992) model was used to assess the impacts of three climate scenarios: the *core* scenario (Oregon State University, OSU), the *wet* scenario (Max Plank Geostrophic Ocean, ECHAM3 TR) and the *dry* scenario (United Kingdom Meteorological Office, UKH1). In addition, assessments of incremental changes were combined with observed climate data of rainfall and temperature to construct additional climate change scenarios.

In the model, wheat and potatoes yield reductions (YR) in rain fed areas and net irrigation requirements (NIR) in irrigated areas were predicted for the year 2050, under the three climate change scenarios. The results represented the combined effect of change in both temperature and precipitation. They were compared with yield reduction and net irrigation requirement results using observed climatic data.

According to CROPWAT estimates for the present situation potatoes actual water use is approximately 10% more in Marib than in Seyoun; a result that could be mainly associated with higher radiation load and wind speed and relatively drier air prevailing in Marib. Wheat shows almost no vulnerability to climate change. This conclusion may support the idea that wheat production in Marib area will have substantial potential.

Other signs of crop production vulnerability under expected changes in temperature and precipitation could be related to the incidence of pests and the soil conditions. Increased temperatures coupled with the same or higher precipitation generally provide better conditions for the development of diseases and other pests including weeds. Soil physical conditions are sensitive to potential climate change. If precipitation increases and temperature either remains constant or increases, the permeability of soils in the semi-humid region (Ibb) will change. This will thus expand the area of land vulnerable to flood hazard and poor drainage.

The following sections present the data and results and gives suggestions for follow up studies.

Main results

Water

In Yemen water is extremely scarce. Therefore groundwater consumption is very high. The annual decline of aquifers levels in most water basins averages 1-8 meters. All over the country, current water quantities pumped are estimated at 138% (2.8 billion cubic meters) of the annual renewable quantity, which is estimated at around 2.1 billion cubic meters. In the mountains, extraction is as much as five times the quantity of precipitation. It is projected that at current levels of extraction the water reservoirs in this region will dry up in a period of fifty years.

Water is the limiting factor for crop production. In the irrigated areas wheat production is out of the storage risk, with no direct effect on the yield, and the water requirement is 450 mm over the growing season. No wheat production can be obtained in some years in rain fed areas, where the water requirement is over 250 mm. The highest water efficiency was 1.16 kg/cubic meter with 400 mm water use. Generally, crop and irrigation patterns exacerbate the water scarcity and result in salinisation of aquifers.

Soils

In general, soils in Yemen are calcareous, with pH between 6.8 and 7.5. They have high levels in potassium, and low levels of nitrogen and phosphorous. Phosphorous was the primary limiting factor in Dhamar. $CaCO_3$ may affect crops chemically and physiologically. Organic matter is lost in these soils; this means that the soils have low capacity for providing available nitrogen for crops. Accordingly, Yemen's soils need nitrogen supplements for all crops, except legumes.

There were difficulties in predicting whether climate change would affect soil nutrients; therefore it was assumed that there would be no effect. However, physical conditions will be sensitive to potential climate change. If precipitation increases, and temperature either remains constant or increases, drain ability of soils in the semi-humid areas (Ibb) will change. This will expand the area of land vulnerable to flood hazard and poor drainage.

Crops

New and high yielding crop varieties were introduced in Yemen many years ago. These varieties require high levels of inputs such as water and fertilisers. These varieties are very often resistant to diseases and pests compared with the indigenous or old races of wheat. The main disease problem is rust, particularly yellow and stem rust. Aphids are the major pests. They decrease the yield by about 10%, particularly under irrigation conditions. The use of pesticide to protect wheat production is uncommon in the study areas.

Wheat and potatoes yields varied from year to year and area-to-area. The average yields of wheat at the national levels are less than 1.3 ton/ha (1981-1998). The highest yields were in 1986, 1987, 1988 and 1989, whereas the lowest were in 1983, 1984, 1991 and 1997. The average potato yields were fluctuating in the study areas. From 1990 to 1996 these yields increased in Marib and Seyoun with an average of 15.4 ton/ha. In Ibb the yields increased in the period 1985-1986 with an average of 20.5 ton/ha, whereas the average was 12.5 ton/ha in the period 1994-1996.

Socio-economic implications

Agriculture accounts for 58% of employment in Yemen. Therefore, the depletion and degradation of natural resources, particularly water and soil, have significant implications for the livelihood of a majority of the population. Wheat price subsidy increase may stimulate rain-fed wheat growth.

It was estimated that women contribute about 60% to the total labour in the agricultural sector. Data also indicate that 96% of children in rural areas are engaged in agriculture work. Child labour has grown considerably over the last years, which is considered a significant socio-economic problem.

Limitations and dissemination

In Yemen very few studies were conducted in the field of climate change and its impacts on natural resources. The main reason for this is the lack of systematic and reliable meteorological, climate and other relevant data that are critically needed to conduct such studies. Furthermore, local experts and researchers in the field of climate change are very scarce and have difficulties to participate in international activities and programs related to global climate change.

Yemen has significant financial constraints in conducting studies, surveys and gathering scientific data. Only three studies were conducted over selected sites to assess the negative impact of climate change and the results seem to be very generalised and not very representative, therefore, much effort is needed to complete the studies and cover more study areas for further understanding of the impacts and adaptation at the national level. In spite of these problems encountered during phase one of the project, public awareness in climate change issues has risen and improved significantly. This was due to conducting seven awareness workshops and seminars in various cities and towns within the country.

2.13.4 Experiences, lessons learned and follow-up research

The Initial National Communication in Yemen showed generalised results and findings, which were useful in fulfilling Yemen's commitment towards the UNFCCC and Protocol Kyoto. It also helped with the establishment of a database within EPA about Yemeni expertise in these fields and collection of reasonable amount of data and relevant references. Furthermore, it raised the awareness to the public about the impacts and threats on climate change.

However, there is a need for conducting more research and studies to clearly understand the effects of climate change on agricultural productivity. As noted, there used to be no concern about the effects of climate change on crops that more sensitive to climate change, including pulse, horticultural and cash crops. It is important to understand the sensitivity of these crops to climate change, which could affect the agricultural productivity country, particularly in remote farmlands. It is of crucial importance to understand how the projected consequences of climate change would affect the agricultural productivity.

Change in climate may lead to a changed subsidy policy and increase demands of agricultural inputs for lands, particularly pesticides and fertilisers. These resources are scarce, especially in remote rural areas. Most farmers lack funds for new investments for adapting to climate change. Adaptation policies can make sense already in the case of drought and floods because of climatic variability as extreme events. Adaptation can help to reduce damage in short-term, regardless of any longer term changes in climate. It is of vital importance to introduce appropriate water-saving irrigation practices to contribute to the mitigation of effects of climate change on agriculture.

2.13.5 Policy implications

The Yemeni Government adopted several policies that in some cases led to efficient and fruitful results. The most important policies include:

1. Subsidisation of consumer prices, especially of wheat, and thus decreasing output prices, subsidisation of diesel fuel and credits for pumping and other farm machinery at low interest rates, resulting in lower water prices;
2. The dominant role of the government in marketing and distribution of farm inputs;
3. Subsidies on other inputs, such as fertilisers, pesticides, fruits, vegetables and other imported grains and seeds;
4. Improvement in irrigation practices. This has led to dramatically less groundwater consumption and a significant increase in agricultural yields.

The Government adopted a Gender Food Security and Agricultural Policy. Policies also address practical and strategic gender needs in training, research, agricultural extension, credits, micro enterprise and marketing. Recently regulatory measures, as national acts, have been issued in Yemen for the following aspects:

1. Pesticide use (The State Law of plant pesticide was issued in 1999);
2. Water use (The water Law was issued in 2002);
3. Seeds and agricultural fertilisers (Ministerial regulations and internal circulars):
   - To register kinds of certified seeds including seeds and seedlings;
   - To regulate seed production and marketing;
   - To protect ownership of invention patents;
   - To regulate agricultural fertiliser use and protect human, animals and the environment from their direct and indirect adverse effects.

The methodologies and studies used by the study team were in line with the policy needs, however these methodologies could be developed further or additional methodologies could be introduced in follow-up studies. The aims of these policies are to introduce subsidies or taxes to encourage the growth of crops that are better resistant to the (future) climate conditions. Many farming technologies such as efficient irrigation systems provide opportunities to reduce dependence on natural factors such as rainfall and runoff. Also, the effects of market liberalisation must be studied further in the light of climate change.

Main products

EPC (2001). *Initial National Communication under United Nations Framework. Convention on Climate Change*.

EPC (2000). *An assessment of climate change on agriculture in the Republic of Yemen*. Final report submitted by the Agriculture Team to EPC/UNFCCC.

EPC (1999). *Report on Climate Change Country Study in Yemen and Enabling Yemen to prepare its First National Communication in Response to its Commitments to the UNFCCC*.

Republic of Yemen (2001). *Initial National Communication of under the United Nations Framework Convention of Climate Change*, Environmental Protection Council, 72 p.

2.14 Zimbabwe

Washington Zhakata[32], Norbert Nziramasanga[33] and Margaret Sangarwe[34]

2.14.1 Introduction

Zimbabwe is the second largest energy user in Southern Africa following South Africa. The regional energy sector is dominated by coal with hydroelectricity being available mostly in countries North of Zimbabwe. The Zambezi River is the major source of hydro-electricity at present in Zimbabwe but the Inga falls on the Zaire River offer the greatest potential for hydroelectricity in Africa. The current domination of coal is expected to continue due to the low costs of coal. Since the use of carbon intensive fuels is dominant there is scope for initiating activities to optimise energy use in the country.

Zimbabwe is also prone to frequent droughts and in recent years flooding has affected communities in the southeastern parts of the country too. This in a way reinforces the

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[33] Southern Centre For Energy and Environment

[34] Ministry of Environment and Tourism

need for the country to participate in activities that may mitigate the impacts of the changing climate. Therefore, a study on climate change impacts and adaptation in the agricultural sector, and mitigation opportunities in the energy sector has been conducted. In this section we will focus on the greenhouse gas emissions mitigation assessment activities.

In this section we will focus on cogeneration in Zimbabwe industries. In brief this NCCSAP study sought to identify win-win opportunities in industrial energy efficiency improvement where companies despite knowledge of the opportunities have not been able to implement such opportunities. Hence, the study identified the implementation barriers and tried to make recommendations for barrier removal.

2.14.2 Approach

The activities in Zimbabwe were centred on the identification of opportunities for climate change mitigation through emission reduction. The focus was on industrial energy use with a limited exercise to consider the potential for utility level efficiency improvement. The project concept was to identify opportunities where energy efficiency improvement would yield a win-win solution but where the company had not implemented the measure, i.e. the opportunity would save both money and the environment. The main objective was to identify the barriers that were keeping the measure from implementation and how these barriers could be removed. As a result it was evaluated to be more strategic to identify options that had been analysed earlier since these would be interpreted for the companies and might show ways for them to overcome the barriers of implementation.

Zimbabwe has had a significant number of studies in the context of energy efficiency improvement and climate change. A study carried out under the support of Canadian International Development Agency from 1989 to 2001 looked at industrial energy efficiency and how capacity could be built within the local institutions and individuals to implement efficiency improvement measures in the SADC industries. Zimbabwe was part of this study and several training courses were run which resulted in the identification of options for energy efficiency improvement. Other studies carried out in preparation for the first national communication to the UNFCCC also yielded several options for energy efficiency improvement. In more recent years UNIDO sponsored activities to 'learn by doing' in building capacity for implementing CDM projects (see also section 4.2.2). These studies also sought to identify barriers to efficiency improvement or implementation of CDM projects by conducting workshops and raising awareness on institutional roles in implementing CDM. All these activities linked very well with NCCSAP by providing background information and by pointing consultants to cases with greatest potential.

Several consultants carried out this study. Each consultant was responsible for a case study, which in most cases was a single industrial plant. Some consultants handled more than one industrial plant but with each plant representing a case study. In total nine case studies were carried out. The consultant visited the plant and compiled information on the processes used and the energy use patterns. Where possible the consultant discussed the opportunities for energy efficiency with the plant management or technical people.

The objective of the discussions was to identify the major barriers that were preventing the implementation of win-win opportunities that were otherwise well understood.

After data collection the consultant built an option for energy efficiency improvement and tried to quantify the potential for greenhouse gas emission reduction and the other local and global environmental benefits. Where there was no sufficient technology data the consultant got assistance from the technical support team that included Southern Centre for Energy and Environment, IVM and ECN.

Two report back workshops were held where the consultants presented their findings and get feedback from the participants. This interaction allowed the stakeholders to provide comment on the work and also to guide the consultants in data collection and analysis. In the Bindura Smelter and Refinery case the stakeholders developed a priority list of the opportunities that were studied. We will focus on this case in the following paragraph.

2.14.3 Results of the Bindura smelter and refinery study

Zimbabwe has had experience with steam/electricity cogeneration in the sugar industry. All other industries have not previously considered cogeneration as an option that they could successfully pursue. The Zimbabwe iron and steel company, ZISCO, operates a power station fired on blast furnace gas. This is similar to cogeneration but is more of a power plant taking advantage of waste energy from the blast furnace without much need for coordination between fuel production and fuel use since the plant can be idle when the blast furnace is operational. In any case the blast furnace gas can be used for other heating operations in the mill. The identification of the cogeneration opportunities at the Bindura Smelter and Refinery helped in highlighting the potential for new cogeneration opportunities that seeks to address national problems of coal supply and security of electricity supply. The plant has an ideal situation because the existing boilers need to be replaced and the cost of coal transport has risen because of a poor transport network. In addition, grid electricity supplies are intermittent due to limited internal generation capital.

The Bindura Smelter and Refinery processes nickel ore from the adjacent nickel mine. The bulk of the energy used in the smelter is for heating ladles and for producing steam used for maintaining the high temperature in the electrolysis plant. The company is keen on energy efficiency improvement since the energy input presents one of the major production costs. In addition the company exports all its output and the international nickel prices are determined outside the influence of the plant. Efficiency improvement is therefore a key option for increasing margins.

The options for efficiency improvement include upgrading the smelter technology to include energy recovery from the sludge or to employ high technology smelters where the heating effect would be more accurate, e.g. with plasma based processes. At a simpler level the boiler efficiencies could be improved by replacing the existing shell type boilers with more modern units with higher design efficiencies and flue gas heat recovery. An option that presented itself earlier but was only analysed later was the production of electricity from the steam produced by the boilers before sending it to the electrolysis plant. The electrolysis plant accepts low-pressure steam at a low temperature. The boilers are capable of high-pressure steam but are operated at 10 bars that suits the electrolysis plant.

The low steam pressure reduces the energy efficiency for the process. Hence the smelter uses more coal than is necessary and at the same time it is drawing electricity from the grid for driving the conveyors, electrolysers and other process equipment. The design efficiency of the existing boilers is about 74% whilst new boilers could have an efficiency as high as 85%. The existing boilers were installed in 1969 and 1974 and are now due for replacement. It is in this context that installation of a cogeneration unit is being considered. The boilers would be replaced by higher pressure units of preferably 40 bar. A backpressure turbine would be installed and the exhaust steam from the turbine would be used to heat the electrolysis plant. A quick calculation showed that the turbine would produce about 3 MW of electricity. This would be about 20% of the total plant load, which is 15 MW. The use of high pressure steam results in the production of additional energy from the same quantity of coal. This would also reduce the need to transport coal. Road transport has increased dramatically in the last years at the cost of to rail transport for moving coal from the coal mine to the plant.

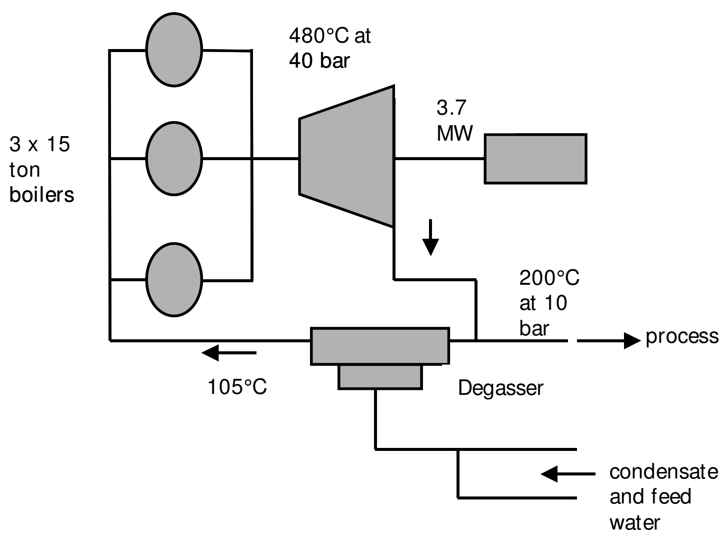

Figure 2.15 Proposed Cogen Layout.

The proposed option was well received by the plant management who thought it offered a realistic possibility for them. What appeared to be the major barrier was the lack of experience with cogeneration of this type.

The issue of data and information on the proposed cogeneration plant presented a problem for the consultant. The equipment cost was not readily available and manufacturers tend to compute costs on a case-by-case basis, which would require more detailed design. The project did not provide for this, as the objective of the project was to get indicative figures. In an attempt to acquire cost figures a search for similar plant was made on Internet. The findings were mostly for individual equipment such as turbines or alternators and not for a complete plant. The costs of equipment installed vary significantly from site to site. Hence it would have been better for the project to apply cost figures from a complete project as opposed to addition of individual unit prices. Eventually generic figures were used. These were based on known average cost for thermal fired plant.

Zimbabwe has a high potential for the installation and use of cleaner technologies with win-win benefits. Despite several studies having been carried out there are major impediments to the immediate implementation of these technologies. The barriers are elaborated below.

Financial barriers

The costs of new technologies are not necessarily the reason for slow adoption of cleaner technologies. Companies seem to be focused on other urgent issues. Other, more urgent technologies actually have been implemented. Hence, the ability to present bankable projects is not necessarily the main reason for implementing climate friendly and cost saving technologies.

Due to the current macro economic situation in Zimbabwe, industry is facing very high inflation and interest rates that make it difficult for companies to secure new loans for investments in modern, more efficient, technologies. In addition, the devaluation of the currency rate also made imports more expensive. These factors lead to high uncertainty on future prices and costs and investors therefore tend to delay their investments.

Awareness of cleaner technologies

In cases where companies have installed new technologies they have not considered additional components that could have achieved cleaner performance with lower cost. This includes the turbine installed at Hypo Valley where higher pressure steam would have increased the volume of power produced and the new pumps installed at Bulawayo pumping stations where upgraded controls could have allowed for optimum pump sizing as opposed to the traditional 10% over sizing. This in a way points at lack of up to date information on technology improvements.

Limited technology assessment skills

Motivation to upgrade technology is often a result of existing skills to assess the benefits and present a convincing story to the decision makers. Climate change is not so high on the corporate agenda hence technical staff in industry does not spend time looking for climate friendly opportunities. As a result skills are not developed and technology assessment for environment protection is not used as a criteria for investment.

2.14.4 Experiences and lessons learned

The study was structured to rely on previous work for identification and analysis of energy efficiency improvement options.

In the absence of previous work the study was limited in terms of identification of barriers to implementation of the options since the potential investor would not have had knowledge of the option.

On the other hand there was room to discuss with the company management in an attempt to identify what the barriers could be, provided the management was in a position to respond quickly to a new idea. Relying on existing reports required that the technical staff in the company be familiar with the studies. Where this was the case it was easy to identify the barriers. In other cases the staff did not offer suggestions on what the barriers could be. Sable Chemicals is one case where staff was familiar with the options. It was therefore fairly easy to hold a discussion on the potential barriers with the technical managers. This also applied to hippo Valley Estates where the company had installed a 20MW turbine and was in the process to negotiate a power purchase agreement with the utility. In the case of Bindura Smelting and Refinery and the pumping stations in Bulawayo it was much more difficult to discuss barriers because the opportunities were just being identified.

Technology information was limited for all case studies. Data was generally available in the form of nameplate data for machines but more detailed information on operating parameters and alternative technologies was generally not available. The key technical contacts in the companies were also limited on their knowledge of this information. The project requires a multidisciplinary team where apart from appreciation of energy efficiency improvement, the team would need to be able to make preliminary designs to enable determination of capital requirement and other technical data. This missing data restricted the ability of teams in determining the emission levels and the potential benefits of efficiency improvement. Therefore it was concluded that the findings could be used as a basis for more precise analysis in future.

The problem is that boiler costs needed to be split as cost for a normal boiler as is installed and cost of a higher pressure boiler as proposed. This would yield the incremental cost of the improvement. This calculation could not be done, however, because boiler manufacturers in the region could not provide this information since they do not manufacture boilers with pressure above 20 bars as a standard product. Given the interest shown by the company management it would be important for them to seek the services of a cogeneration expert so they can get a more detailed analyses of the option with more accurate cost and engineering design figures.

The workshops and other discussion forums that were held showed that there is general interest in energy efficiency improvement in industry. Even though there was no immediate knowledge of policy options to encourage the implementation of identified measurers there was a general agreement that something has to be done at high level to encourage implementation of the measures.

2.14.5 Follow-up research

While there are some aspects of climate change driven policy that are unique, it has been identified that many of the activities of a successful climate change technology transfer program provide benefits toward a broad range of development objectives, and the lessons learned through the needs assessment process can be applied to a range of development challenges where technology transfer and international cooperation can contribute.

The NCCSAP mitigation studies have just been completed. Follow-up research areas have been identified in order to implement the recommendations that were identified in the main study. It has been identified that Zimbabwe has a high potential for the installation and use of cleaner technologies with win-win benefits. Despite several studies having been carried out there are major impediments to the immediate implementation of these technologies. Follow-up research needs to be focused on finding means of addressing the issue of slow adoption of cleaner technologies. Companies seem to be focused on other pressing issues such that there is absence of motivation to concentrate on optimisation of activities including installation of technology for cleaner production reasons. One area that needs researching on is how indigenous capacities in the country can be enhanced in order to develop and transfer technologies.

From the studies, it also emerged that there is need to explore the ways in which companies can consider installing additional components that could achieve cleaner performance with lower cost.

One of the most important future researches as a follow-up to the NCCSAP is on the issue of assessing the levels of motivation to upgrade technology. This will entail the establishment of collaborative partnerships between key stakeholders with the common purpose of enhancing technology transfer. A way has to be found for the government to be involved at all stages. Enhancement of capacity of resident skills to assess the benefits and solicit commitment of decision makers will be paramount. It was observed in the study that climate change is not so high on the corporate agenda hence technical staff in industry do not spend time looking for climate friendly opportunities. As a result skills are not developed and technology assessment for environment protection is not used as a criteria for investment. There is a need to design an integrated program for barrier removal that would see accelerated technology upgrading in industry.

2.14.6 Policy implications

The climate change issue is a new concept in Zimbabwe both in terms of its science and policy implications. The understanding of this subject – its scientific basis, institutions, and relevance to Zimbabwe’s economy – are mainly restricted to a few institutions and individuals working on the subject. It is not possible, therefore, that Zimbabwe would, at this stage, have a stated or fully considered national perspective on policies and measures to respond to climate change. However, climate change activities in Zimbabwe have been growing since its participation at the Rio Earth Summit in 1992.

It is worth to note that recommendations to incorporate climate change policies into Zimbabwe development plans have been captured in the new act on the environment ‘Environment Act of Zimbabwe’ of 2003 (EMA). What is significant at this point is that Zimbabwe has included climate change in its national legislation. The NCCSAP project results were well circulated amongst various stakeholders and have played a significant role in the formulation of climate change policy in Zimbabwe.

2.14.7 Conclusions

With the experience gathered from these studies, Zimbabwe is now in a better position to conduct more comprehensive assessments of greenhouse gas emission inventories, mitigation analyses and vulnerability and adaptation studies

There are viable opportunities for climate change mitigation in Zimbabwe industry. These opportunities come with major barriers to implementation, which require joint effort between public and private sector decision makers to overcome. Even though studies have been carried out that analyze these barriers there is need to solicit commitment from all parties for the successful implementation of these opportunities.

Several barriers appear to limit the adoption of win-win technologies in Zimbabwean industry, such as lack of cost information, lack of interest of plant managers and hyperinflation. As a result policy change, awareness building and energy pricing are taken in isolation and cannot achieve the desired results of cleaner technology. There is a need to implement an integrated program for barrier removal that would see accelerated technology upgrading in industry. The program could start by pursuing those options that are more promising it terms of financial and economic benefits as well as a wider market for application.

3. Cross country syntheses

3.1 Introduction

In this chapter the technical consultants compare the study results in all countries sector by sector. They summarise the main results and explain the similarities and differences between the countries. This chapter includes the following sections: Emission inventories (3.2), Mitigation assessment of the energy sector (3.3), Adaptation and water resources (3.4), 1 (3.7).

3.2 Emission inventories

Michiel van Drunen[35]

3.2.1 Overview

An overview of the main results from the emission inventories, linked to some general information about the countries is presented in Table 3.1.

Table 3.1 Comparison of various key characteristics of the three countries studied in 1994 (1 Gg equals 1000 tons).

	GDP/cap ('94 US$)	Population (mln)	Net GHG emissions per capita (t CO_2-eq)	Net total GHG emission (Gg CO_2-eq)	Largest GHG Contribution	2nd largest GHG contr.
Bolivia	870 ('95)[c]	7.5[d]	8[d]	61,163	Land use change (65%)	Agriculture (18%)
Kazakhstan	2442[a]	16.2[a]	15	212,613	Energy (89%)	Agriculture (8%)
Suriname	916[b]	0.40[b]	14	5,626	Land use change (52%)	Energy (36%)

[a] Initial National Communication of the Republic of Kazakhstan (1998).
[b] Suriname Central Bank & Suriname Central Bureau of Statistics. As found on www.suriname.org, nov. 2000
[c] Data from the World Bank Group; taken from www.worldbank.org, Nov. 2000.
[d] 1994 population estimated at 7.5 Mln, from the CIA year 2000 estimates of population (8.2 Mln) and population growth rate (1.83%).

The per capita emissions are not very low compared to Annex-I countries. For example, in 1994 the per capita GHG emissions in the EU-15, The Netherlands and the United States were 10, 15 and 24 t CO_2 equivalents, respectively. However in these countries most of the emissions result from the energy and industry sectors.

In Table 3.2 the greenhouse gas emissions by sector in the three countries investigated are summarised. Kazakhstan, as the most industrialised country has by far the highest CO_2 emissions, as can be seen from the contributions from the energy sector. Bolivia and

[35] See 1

to a lesser extent Suriname emit significant amounts greenhouse gases from land use change, mainly resulting from deforestation. In Kazakhstan, there was a net uptake of CO_2 by plants or trees in managed areas (6,672 Gg).

In all countries there are significant contributions of methane emissions to the total amount of GHG emissions: 22%, 19% en 15% for Bolivia, Kazakhstan and Suriname, respectively.

Table 3.2 Comparison of the GHG emissions by sector of the three countries studied (1994 figures in Gg CO_2 equivalents).

	GHG	Bolivia[1]	Kazakhstan[2]	Surinam[3]
Energy	CO_2	7,646	178,252	1,996
	CH_4	1,870	17,735	3
	N_2O	62	40	3
Industry	CO_2	394	1,014	48
Agriculture	CH_4	10,275	17,388	629
	N_2O	536		6
Land use change	CO_2	38,617	-6,627	2,718
	CH_4	1,148		197
	N_2O	118		19
Waste	CH_4	429	4,811	7
	N_2O	68		
Total	CO_2 eq	61,163	212,613	5,626

1 Source: First National Communication Bolivia (2000).
2 Source: Initial National Communication of the Republic of Kazakhstan (1998).
3 Source: C.R. Becker *et al.* (1999). Greenhouse Gas Emission Inventory for Suriname 1994.

3.2.2 Bolivia

In 1994 to total GHG emissions in Bolivia was estimated to be 61,164 Gg CO_2 equivalents. CO_2 emissions related to deforestation account for by far the largest GHG contribution. CO_2 from deforestation makes up 65% of weighted GHG emissions and 83% of the total CO_2 emissions. Compared to this all other sources are relatively small. CH_4 emissions, mainly from agricultural sources, make up 22% of GHG emissions and the contribution of N_2O is marginal (1.3%).

When looking at the distribution over the sectors responsible for the GHG emissions, the figures are also remarkable: energy and agriculture play a relatively small role in the total GHG production (16% and 18% respectively) and deforestation related emissions account for 65% of GHG emissions. However the uncertainty of the latter contribution is estimated to be 35%. The industry and waste sectors both contribute less than 1%.

3.2.3 Kazakhstan

An important factor to take into account when assessing the emissions of GHGs for Kazakhstan is the economic decline that took place over the period studied. From 1990 to 1994 Kazakhstan's GDP decreased by 40%. This has resulted in an overall decrease of GHG emissions of 33%.

The largest contributions to GHG emissions by far (89% in 1994) were emissions, particularly CO_2, from the energy sector. The energy production sector relied heavily on coal (88% in 1994), which typically has a high CO_2 output per unit energy. The second largest contribution to GHG emissions (in CO_2-equivalents) was from agriculture, mainly as a result from CH_4 and N_2O emissions.

3.2.4 Suriname

An important aspect of the emissions characteristics of Suriname is the use of energy (both fossil fuel and hydroelectricity) by the bauxite industry, which consumes 73% of all the energy in the country. A larger source of CO_2, however, is deforestation, which accounts for 52% of the emissions. The CH_4 emissions are 75% attributable to Agriculture (rice paddies and livestock). Contributions of other GHGs are negligible (<1%).

In the emission inventory (Becker et al, 1999), no attempt was made to estimate uncertainties. Probably, the uncertainty of the total emissions amounts at least the percentage indicated by Bolivia for the contribution of land use change (35%).

3.2.5 Discussion and recommendations

Data availability

All the countries that had conducted an emission inventory had used the IPCC methodology as described in Subsection 1.3.2. Although this was considered a good methodology in general, most countries had difficulties with some aspects of the IPCC methodology.

First of all, activity data were not always available. This was especially the case for land use change and forestry, and waste and biomass consumption. The privatisation of government institutions was given as one reason for the difficulty in gathering data.

A second problem that was encountered by the countries was a poor fit of the bottom up and top down methodology. The main reason for this is probably the aforementioned lack of data, but country-specific circumstances can also increase the gap between the two approaches. In the case of Suriname for example, smuggling of fuel creates a discrepancy in the data, but it is very difficult to deal with this in a systematic way. Furthermore, the IPCC guidelines do not cover this particular case.

Emission factors

On the issue of emission factors, it was generally acknowledged that region specific emission factors are needed, especially for livestock, coal production/consumption and land use. To generate these emission factors a few suggestions were made to improve access to relevant data during the Amsterdam workshop (Dorland *et al*., 2001). One suggestion was that groups of countries in a region that have similar problems conduct research together. Another suggestion was to improve access to relevant studies for region specific factors by giving more attention to networking among countries, for example by making use of the internet.

In the meantime the IPCC has set up an emission factor database and an electronic discussion group at its Japanese website (http://www.ipcc-nggip.iges.or.jp/).

Dealing with uncertainty

There was some comment on dealing with uncertainty in emission inventories. The IPCC guidelines for dealing with uncertainty were found to be difficult to adhere to. In Suriname they did not even make an attempt to make an uncertainty analysis, because they did not know how to do this based on their data and experience.

To improve the general quality and usefulness of the emission inventories, the researchers would like to be more certain that the most important sinks and sources of GHGs are indeed those that the emission inventory identifies, and that the magnitude of these sinks and sources is accurately known (Dorland *et al.*, 2001). In Bolivia and Suriname the most important source, land use change and forestry, is the most uncertain. Therefore more research is needed to increase the certainty of the figures for deforestation and reforestation. Because of the large differences between and within countries, research needs to be directed to the generation of region specific emission and growth factors.

3.3 Mitigation assessment of the energy sector

Nico van der Linden[36] and Jan-Willem Martens[37]

3.3.1 Introduction

One of the objectives of a mitigation assessment is to identify the potential of environmentally sound technologies that are required for reducing GHG emission targets in non-Annex I countries. Environmentally sound technologies can be defined as technologies that are:

- More sustainable, less polluting and more efficient than substitute;
- Compatible with national socio-economic, cultural and environmental priorities.

To achieve a sustainable application of environmentally sound technologies in developing countries, these countries require assistance with developing human capacity (knowledge, techniques and management skills), developing appropriate institutions and networks, and with acquiring and adapting specific hardware. Given the importance of taking into account the local sustainable development priorities in the technology transfer processes, it is clear that the sustainable transfer of mitigation technologies is country specific, sector specific, technology specific and user specific.

3.3.2 Analysis

In the framework of the NCCSAP phase I study, assistance has been provided to the national mitigation teams of Bolivia, Yemen, Zimbabwe and Mongolia. The type of assistance provided differed per country. For Bolivia and Yemen the assistance involved training on the LEAP model (see Subsection 1.4.2) and the development of LEAP version that could be used to evaluate the identified GHG emission reduction options. The type of assistance provided in Bolivia and Yemen consisted of:

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[36] See 2

[37] See 3

- Update of the 1990 inventory of greenhouse gas emissions; and
- Identification and evaluation of options to reduce greenhouse gas emissions;
- The emission inventories were based on the specifications of the United Nations Framework Convention on Climate Change (UNFCCC) and the method applied has been taken from the Intergovernmental Panel on Climate Change (IPCC).

With regard to the identification and evaluation of options to reduce GHG emissions, the steps taken included:

- Design of a LEAP version for Bolivia/Yemen;
- Design of a baseline scenario;
- Evaluation of various reduction options.

In Zimbabwe and Mongolia the analysis of mitigation options was already completed and the activities were focused on barrier analysis and policy formulation. The activities in Zimbabwe and Mongolia included:

- Identifying financial and institutional barriers to the implementation of promising GHG emission reduction options;
- Formulating policies and implementation strategies for GHG mitigation;
- Developing promising mitigation projects.

Table 3.3 Main characteristics of the activities in Bolivia, Yemen, Zimbabwe and Mongolia.

	Bolivia	Yemen	Zimbabwe	Mongolia
Implementing organisation	Programa Nacional de Cambios Climaticos (PNCC), Ministry of Sustainable Development and Environment. PNCC had subcontracted the Chemical Institute of the University of San Andres to conduct the emission inventory.	The Environmental Protection Council (EPC). The EPC has established working groups responsible for conducting the mitigation study and the emission inventory. The mitigation group consisted of scientists from the University of Sana'a.	Climate Change Office of the Ministry of Mines, Environment and Tourism. The Southern Centre for Energy and Environment in Zimbabwe was subcontrated to work on the mitigation analysis.	The Institute of Meteorology and Hydrology of the Ministry of Nature and Environment. A steering committee was formed consisting of representatives of other Ministries and key stakeholders outside the government.
Methodology	GHG inventory for 1994 up to 2030 Design of LEAP model for Bolivia Development of reference scenario Identification and evaluation of GHG emission reduction options Construction of aggregated cost abatement curve	GHG inventory for year 1990 Design of LEAP model for Yemen Development of reference scenario Identification and evaluation of GHG emission reduction options Construction of aggregated cost abatement curve	Identify institutional/ financial barriers To draw up the plan of operations To train the Zimbabwean experts on the technical, financial and institutional aspects To comment on interim and final reports	Prepare a longlist of mitigation options Identify stakeholders Prepare shortlist of mitigation options jointly with the stakeholders involved Conduct prefeasibility studies for shortlist Identify potential projects and funding possibilities Prepare implementation strategy Disseminate the information through workshops
Implementation	Duration 18 months Two missions and back up support Delays due to capacity constraints with implementing organisation Limited expertise in terms of number of staff	Duration 18 months Two missions and back up support Delays due to political circumstances Limited expertise in terms of knowledge	Duration 25 months Three missions and back up support Delays due to political circumstances Sufficient expertise in terms of number of staff	Duration 22 months Three missions and back up support Delays due to unavailability of local experts Limited expertise in terms of number of staff

Bolivia	Yemen	Zimbabwe	Mongolia
		and knowledge	Considerable overlap with other donor pro-grammes

Table 3.4 Main results of the mitigation analysis in Bolivia, Yemen, Zimbabwe and Mongolia.

Bolivia: Reduction options
Re-division of the expansion of the power sector (-100 US$/ton CO_2)
Increase in the use of gas in transport sector (-25 US$/ton CO_2)
Efficient lighting in the commercial sector (-20 US$/ton CO_2)
Efficient commercial use of biomass (-15 US$/ton CO_2)
Efficient use of biomass for cooking (-10 US$/ton CO_2)
Reduction of gas burning associated with the exploitation of oil (-10 US$/ton CO_2)
Energy conservation in industry (-5 US$/ton CO_2)
Efficient lighting in the residential sector (15 US$/ton CO_2)
Efficient cooling in the residential sector (20 US$/ton CO_2)
Reduction of electricity consumption in the commercial sector (25 US$/ton CO_2)
Increase of the use of solar energy (60 US$/ton CO_2)
Increase of the use of gas in the residential sector (175 US$/ton CO_2)
Yemen: Reduction options
Efficient stoves in the rural areas (-17 US$/ton CO_2)
Efficient irrigation (-16 US$/ton CO_2)
Shift to gas turbines in the power sector (-15 US$/ton CO_2)
Efficiency improvements in commercial sector (-7 US$/ton CO_2)
Efficient lighting in rural areas (3 US$/ton CO_2)
Efficient lighting in urban areas (50 US$/ton CO_2)
Efficiency improvements in transport sector (60 US$/ton CO_2)
Zimbabwe: Barriers identified
Lack of financial resources. The interest rate is too high and there is a lack of foreign currency
Lack of government backing on some projects
Lack of sufficient data to assess feasibility and viability of possible projects
Lack of appropriate skills and know how by operational staff
Absence of competition and hence no drive to invest in modern technologies
Existence of subsidised energy prices
Absence of a legal framework to guide negotiations of a power purchase agreement
Inability to correctly assess the benefits from the CDM
Mongolia: Contribution to the National Action Plan on Climate Change
A detailed pre-feasibility analysis for eight promising mitigation options: 1) application of efficient mining technology(selective mining, dewatering system, coal handling plant); 2) coal briquetting; 3) Accelerated introduction of PV solar System; 4) Introduction of electric boilers for small, medium sized heat boilers; 5) Good housekeeping measures in industry; 6) Lighting efficiency improvements in built environment; 7) Introduction of new, more efficient small, medium sized boilers; and 8) Introduction of steam saving technology in industry
Gain insight into the barriers that prevent the implementation of identified reduction options
Identification of concrete projects to reduce emissions and possibilities for financing these projects

The following observations can be made from Table 3.4:

- Total identified greenhouse gas emission reduction potentials in the energy sector in Bolivia and Yemen amount to approximately 2,8 Mton and 7 Mton, respectively. A substantial share of this amount in both countries can be achieved with negative costs (no-regret options). Improvement in energy efficiency and a fuel switch (in particular towards natural gas) appeared to be the most promising options to reduce greenhouse gas emissions.;
- The main barriers identified in Zimbabwe include weak institutional framework, immature markets, limited awareness on technology information and current political/economic situation in Zimbabwe. Through detailed energy audits carried out by local consultants at eight energy intensive companies in Zimbabwe a number of options have been identified and evaluated to reduce these barriers. Implementation of these options however appeared difficult due to the current political situation in Zimbabwe;
- In Mongolia, the NCCSAP has supported the development of the Climate Change Action Plan. This plan includes actions to strengthen the national capacity for climate change issues and provides strategies for the implementation of GHG reduction options for the power sector, industry and the built environment.

3.3.3 Follow-up activities

As a result of the assistance provided in the framework of the NCSSAP programme, several follow-up activities have been identified and elaborated which are summarised below.

One of the promising options identified in Bolivia is a substitution of diesel and petrol in the transport sector by compressed natural gas (CNG) or liquefied natural gas (LNG). In Bolivia the vehicle fleet is mainly concentrated in the big cities, causing traffic congestion and local air pollution problems. The energy efficiency of these vehicles is generally very low compared to Western standards. The LEAP model calculations have shown that a conversion of vehicles powered by petrol and diesel to CNG or LPG is cost-effective (pay back periods of 2-3 years) and also results in a substantial reduction of CO_2 emissions.
Based on the results of the mitigation study conducted in Bolivia, a new project has been formulated which aimed at a detailed assessment of the financial, technical and social feasibility of converting private and public vehicles in La Paz and El Alto to CNG and LPG. A project team has been established consisting of ECN, AGAS (national gas distributor in Bolivia responsible for gas distribution and gas sales), Vialle (Dutch manufacturer of LPG equipment) and the PNCC. A project proposal has been submitted to the Netherlands PPP-JI programme. The study started in 1999 and was completed in 2001.

In Yemen a project idea has been discussed with the EPC involving the installation of 1000 Solar Home Systems in the rural area of Yemen (implementation of the option efficient lighting in the rural areas). Two or three locations have been identified which are not connected to the national grid and will not be in the foreseeable future. The intension is to establish a consortium consisting of a PV manufacturer from the Netherlands, a local PV dealer, ECN and EPC. However, so far the required funding for this initiative has not been secured.

In Mongolia a draft proposal has been prepared for the establishment of the ‘Sustainable Energy Centre Mongolia’. It was proposed to set up the Centre based on a twinning arrangement between Mongolia and the Netherlands, which was seen as very promising as Mongolia could benefit from the extensive experience of the Netherlands’s energy efficiency and renewable energy policies and practices. The Sustainable Energy Centre would operate as an intermediate body between the public and private sector with the following primary goals:

- Expertise Centre on energy efficiency and renewable energy;
- Broker and negotiator bringing public and private stakeholders together;
- Policy-advisor to the government;
- Awareness and promotion centre;
- Project initiator facilitating national and international actors to set up energy efficiency, renewable energy and Clean Development Mechanism projects.

The proposal was submitted to the Dutch embassy in Beijing and has been incorporated into the bilateral aid programme for Mongolia.

In Zimbabwe, a potential CDM project was developed together with local counterparts. The project aimed to build a 3.5 MW thermal power plant using wood residues from the nearby sawmill which produces some 84,000 m^3 of wood residue which, at present is underutilised (some wood is used for steam generation). This will ensure the disposal of the waste in an environmentally friendly manner and ensure the use of the renewable energy resource for the benefit of all stakeholders. The electricity produced by the power plant would be fed into the grid and the steam produced could be used in the production process of the sawmill. First preliminary calculations of the economics of this proposed project indicated that it could be a financially viable undertaking if brought under the CDM scheme. A project proposal for a feasibility study has been drawn up containing a detailed description of the project. However, the political situation in Zimbabwe appeared to be a major problem in getting the project funded.

3.4 Adaptation and water resources

Arjan van der Weck[38] and Hans Leenen[39]

3.4.1 Introduction

Vulnerability assessment and development of adaptation strategies (V&A studies) for water resources management have been executed in Bolivia, Ecuador, Ghana, Mali, Suriname and Yemen.

This section describes the results of the V&A studies, the common risks and the identified adaptation strategies associated with water resources management in the above listed countries. The major risks are flooding and erosion due to higher river discharges on one hand and increased water scarcity due to a decrease in average rainfall on the other hand.

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[38] See 9

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Effects of climate change are very much geographically dependent and may thus differ quite widely. Flooding and resulting erosion effects can largely be combated by technical interventions, whereas combating water scarcity problems requires in general a more institutional approach. The latter is related to co-operation between users and water demand management mechanisms. It is therefore concluded that in addition to technical issues, institutional issues need to be addressed in all investigated countries aiming at the prevention of water spilling, and a higher level of cooperation between stakeholders. The concept that needs to be addressed is the recognition of water as an economic good.

Climate change will lead to more precipitation but also to more evaporation. Precipitation will probably increase in some areas and decline in others. Making regional predictions is further complicated by the extreme complexity of the hydrological cycle: a change in precipitation may affect surface wetness, reflectivity, and vegetation, which then affect evapotranspiration and cloud formation, which in turn affect precipitation. Clear answers about the risks of climate change on water resources were not available at the time the studies described here were carried out[40].

From the research in the various countries it follows that the identified risks depend on regional geography and the climate scenario considered (social, economic and cultural characteristics). The major risks may be different for the different countries; however, they can be attributed to one of two categories:

a. Increased risk of flooding and erosion;
b. Increased water scarcity.

Typically the expected problems in Bolivia, Ecuador and Suriname can be associated with category a, whereas the expected problems in Ghana, Mali and Yemen can be associated with category b.

The effects of the two risk categories are primarily:

- Loss of production of agricultural land and more difficult housing conditions;
- Water shortage for all uses, i.e. domestic, industrial and agricultural.

Table 3.5 provides an overview of the vulnerability profiles in the six countries investigated.

[40] IPCC (2001), Chapter 4, currently presents an excellent overview.

Table 3.5 Background on vulnerability profiles (source: Dorland et al., 2001).

Country	Risk	Technical constraints	Legal/ Institutional constraints	Financial constraints
Bolivia	Higher incidence of floods and erosion particularly in the La Paz region.	The technical levels of staff are reasonable to good. Further training is required to improve the capacity for complex assessments. Lack of reliable hydro/meteo and river flow data hamper the assessments of key pilot areas.	The staff of the San Andres University was dedicated and able to learn fast in the field of water resources modelling. The capacity to multi-disciplinary co-operation could be strengthened. The Secretariat of the PNCC functions well as a focal point for climate change in Bolivia. However, future finding is not assured.	Physical adaptation measures can be implemented gradually, integrated in the design of new infrastructure, resulting in an increased cost level, probably requiring international funding.
Ecuador	Risk of flooding due to increased rainfall and river discharge. The southern part of the Gulf is the most vulnerable area.	Sufficiently skilled staff and a well-maintained hydrological database. A strong need for improving river basin management by transferring relevant software and training of staff.	Professional cooperation between the Ministry of Environment, the Hydrological Institute and local researchers.	No information available
Ghana	Water scarcity is expected. The situation of hydropower generation is judged extremely vulnerable. Rain fed agriculture will require irrigation under conditions of climate change.	Relevant experts, know-how and adequate data series are available for complex and multidisciplinary assessments of climate change impacts.	The water resources team has succeeded well in involving a range of institutions and making experts in different disciplines contribute in the present study. Further development in management and coordination skills will be beneficial to future assessments. The recent establishment of the Water Resources Commission (WRC) can be instrumental to give adequate weight to	Physical adaptation measures can be implemented gradually, integrated in the design of new infrastructure, resulting in an increased cost level, probably requiring international funding.

Country	Risk	Technical constraints	Legal/ Institutional constraints	Financial constraints
			the climate change concerns in future water resource planning.	
Mali	Risk of increase of water deficits in agricultural production, in particular for cotton, corn and millet (2 river basins have been studied).	Basic technical skills are available but may need some polishing and further upgrading.	No information	No information
Suriname	Suriname did assess the specific water resource risks in the coastal zone in terms of flooding and increased needs for drainage capacity.	The availability of skilled and experienced personnel at all levels is a major problem.	Staff is well motivated and knowledgeable, but total capacity is limited. Authorities in general vertically structured. Cultural barriers hamper horizontal consultation and multi-disciplinary cooperation.	The replacement of the present gravity drainage by pumping facilities requires international funding, estimated at US$ 170 million.
Yemen	Groundwater resources are insufficient under conditions of temperature increase and rainfall decrease. This will result on the long term in a limitation of further agricultural development due to lack of good quality water. Domestic and industrial water supply are secured, although at higher cost due to a decline of the groundwater level.	Limited capacity, university based study team. Technical skill on graduate level without relevant working experience.	Focal point for climate change issues through Environmental protection Council, including the ministries involved. PMU for climate change management. The continuation of the coordination activities depends on international funding.	No information available

Higher river discharges

The studies on vulnerability of water resources to climate change indicate important variations in the runoff levels, depending on the climate scenarios considered and the basin studied and its location. This risk is typical for river basins with perennial rivers (rivers that flow year-round). It can be concluded based on the studies described here that under different scenarios for the same river basin, both increase and decrease in river runoff can occur. If this is the case, the risks of increased flood levels will prevail in a river basin for which there is no water scarcity to begin with.

Erosion can be seen as a derived effect, although it is not only caused by flooding, but mainly through human interventions. Bolivia, Ecuador and Suriname are typical countries that run a higher flood risk. The country studies indicate that in Bolivia and Ecuador the risk is primarily related to higher river discharges, while in Suriname the flooding risk is related to sea-level rise, causing a need for additional drainage capacity in the Nickery delta area.

Increased risk of water scarcity

This risk is typical for the arid and semi-arid countries. The drier the climate, the more sensitive is the local hydrology. In dry climates, relatively small changes in temperature and precipitation may cause relatively large changes in runoff. Arid and semi-arid regions will therefore be particularly sensitive to reduced rainfall and to increased evaporation and plant transpiration. Many climate models project declining mean precipitation in the already-dry regions of central Asia, the Mediterranean, southern Africa and Australia. Water scarcity is not only reflected in reduced surface water availability, but will also lead to reduced recharge of groundwater aquifers. Ghana, Yemen and Mali are typical countries that run a high risk of water scarcity.

3.4.2 Adaptation strategies

The specific country wise adaptation strategies are presented in Table 3.6. Adaptation strategies to the two listed risk categories comprise in summary the following:

a. Adaptation to increased risk of flooding and erosion due to higher river discharges:

   - Increased drainage capacity;
   - Flood protection and other flood prevention works;
   - Erosion control through reforestation;
   - Changes in land-use.

Combating and adaptation to flood risk requires familiar technical interventions that are already applied elsewhere, or in the country itself. Adaptation would typically require the design and implementation of flood protection works, increased drainage capacity and changes in land use.

b. Adaptation to increased risk of water scarcity:

   - More efficient water use through water and wastewater pricing policies;
   - Improve water availability throughout the year by reservoir management;
   - Introduction of water saving techniques;
   - Inter-basin water transfer;
   - Improved wastewater management;
   - Waste water reuse in non-potable use, such as irrigation;
   - Adaptation of cropping patterns, switching to less water consuming crops;
   - Set-up of a detection and early warning system;
   - Increase mobility of population in case of extreme drought.

Water scarcity is not a new risk for many countries, but a phenomenon that is often already experienced in arid and semi-arid countries. E.g. depletion of groundwater resources is quite common. Climate change requires taking actions in cases where water scarcity problems are already present. Yemen with rapidly depleting groundwater resources is a typical example.

Strategies to combat water scarcity not only require technical interventions, but perhaps more effectively they require institutional interventions related to water use management and water demand management.

Table 3.6 provides an overview of the identified adaptation options in the six countries.

Table 3.6 Adaptation measures.

Country	Identified adaptation measures
Bolivia	Inter-basin water transfers, reduction of water losses from water conveyance and distribution systems, improved wastewater management, more efficient water use in all sectors, introduction of water saving techniques, water and wastewater pricing policies, erosion control (reforestation).
Ecuador	Adaptation measures were not elaborated.
Ghana	Inter-basin water transfers; reduction of water losses from water conveyance and distribution systems; artificial recharge of groundwater to reduce evaporation; improved land use practices and irrigation control to reduce siltation of surface water reservoirs, more efficient water use in all sectors, recycling of water for non-potable uses; introduce cash crops with low water use; diversification of the sources for energy generation (move from hydropower to natural gas or other energy carriers); improved urban planning to avoid damage in areas that may become increasingly flood prone.
Mali	Increase of irrigation quantity through supply from river water or groundwater pumps; optimised regulation of river discharges through reservoir management; implement an early warning system to identify the risk of crop deficits; choice of different crops in agreement with available water; improve the agrometeorological information to the rural population; implement an agrometeorological database system for the farmers in rural areas; increase the mobility of populations in case of extreme droughts.
Suriname	Pumping systems to guarantee adequate drainage of agricultural, urban and industrial land.
Yemen	Water preservation, reduction of water losses, efficient water use, changes in crops.

Follow-up activities

The suggested follow-up by the individual countries is presented in Table 3.7. Ecuador has clearly indicated the necessity for evaluation the economic values of water resources and ecosystems. Actually this approach is extremely important to all countries, and should be elaborated further (see also Section 4.3.2).

Table 3.7 Country wise suggested follow-up.

Country	Follow-up
Bolivia	Incorporation of extreme climatic events (seasonal variation, extreme rainfall, peak floods and droughts)
	Multidisciplinary evaluation of impacts and adaptation strategy
Ecuador	Expand current knowledge and experiences to carry out vulnerability studies in other river basins
	Improve and optimise the hydrometeorological observation networks
	Assessment of economic value of water resources and ecosystems
Ghana	Incorporation of seasonal variation and extreme events (rainfall, peak floods, droughts)
	Adoption of international approach in Volta basin.
	Assessment of the possibility of recharge to groundwater
Mali	Elaborating the study of anticipating optimal strategies in terms of mobilising resources and possible assistance to affected populations
Suriname	Promotion of interdisciplinary cooperation
	Transfer of software models and training of staff
	Set-up of monitoring system
Yemen	Incorporation of VA results into Yemen's national development plan
	Extrapolation of pilot areas towards national level
	Inventory of stakeholders and data for the formulation of an action plan for the water sector

3.5 Adaptation in coastal zones

Marcel Rozemeijer[41], Arjan van der Weck[42], Frank van der Meulen[43] and Rob Misdorp[44]

3.5.1 Introduction

This section presents the cross country sector syntheses of the effects of sea level rise (SLR) on the coastal zones of those countries financed by the NCCSAP. The present vulnerability of coastal areas, due to unsustainable use and coastal degradation, will be exacerbated by the expected SLR and other impacts of climate change. In 1990 the IPCC called for assessments of vulnerability to climate change. A common methodology for Vulnerability Assessment (VA) was developed (IPCC, 1991), to examine coastal vulnerabilities resulting from Climate Change impacts such as SLR (see also Section 1.5.2).

A large number of VAs for different coastal countries has been conducted. During the World Coast Conference (IPCC, 1994) - under the auspices of IPCC - more than 40 coastal countries reported their progress on VAs. Twelve countries reported their pre-

41 See 8

42 See 9

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liminary follow-up on country-wide Integrated Coastal Zone Management (ICZM) efforts, while eleven countries reported on local ICZM area cases studies (IPCC, 1994).

The NCCSAP programme, encompassing eleven coastal countries, presented its results during the World Water Forum 2000 in The Hague (NCCSAP, 2000). The results of these eleven VA studies are reviewed here and the experiences with the application of the IPCC Common Methodology are examined in the light of possible follow-up actions. Four VA studies in Bangladesh, Egypt, Nicaragua and Vietnam are included in the present review as they were carried also funded by the Netherlands Ministry of Foreign Affairs prior to the NCCSAP and for reasons of comparison and exemplary ICZM follow-up activities.

3.5.2 The impacts of sea level rise

This subsection will show that all investigated countries will face severe problems as a consequence of SLR in the (near) future. Table 3.8 gives an overview of the quantification of effects according to the IPCC methodology (IPCC, 1991, 1994). Table 3.9 presents an overview of the countries, the areas studied, the climate change and socio-economic scenarios used in the assessments and the year in which most of the work in the studies was completed. The table illustrates the variety in geographic scope and the scenarios used. The country studies included qualitative and quantitative assessments where possible. In the quantitative assessments primary physical impacts of SLR on the population, the capital value and areas at risk were analysed. Estimates were given in absolute (i.e. number of people at risk, capital value at risk in dollars and areas at risk in km^2) or in relative figures (i.e. percentage of the country's or area's total population at risk. Capital value at risk is given as a percentage of the Gross Domestic Product or area at risk as percentage of the total area). In the IPCC terminology the following vulnerability classes are distinguished: low, medium, high, critical. See Table 3.8 for classes and impact categories.

When comparing Table 3.9 with Table 3.8, it shows a complete range in effects. All NCCSAP countries fall for the different impact categories into different vulnerability classes ranging from 'low' to 'critical'. We will discuss some general aspects. We will not discuss these figures in further detail here, as comparison is difficult due to the different assessment levels and country situations.

The categories of people at risk and area at risk demonstrate a similar pattern of low and medium impact. Most countries are large with a relative small coastal zone that is low developed and sparsely populated. Only Bangladesh, Ecuador, Suriname and Vietnam show a large relative impact of SLR on the population, posing an impact on the whole society.

Table 3.9 also shows that most countries have a problem with the risk of losing large capital investments (capital value at risk: high to critical). Densely populated countries such as Bangladesh and Vietnam are in risk to lose 10 to up to 80% respectively. Even a country with a sparsely populated coast such as Colombia has a risk of loosing 4.5% of the invested capital.

Another category with high to critical impact according to IPCC definitions is that of the wetlands at risk. All countries assessed will probably not be able to finance protection.

One wonders, to what extent the wetlands are really threatened. Probably the natural coastal dynamics could aid in preventing loss of wetland area. A prerequisite, however, is the availability of natural material like sand and silt and a minimal flow of these materials along-shore and on-shore. In general capital investments in the coastal zone (new or existing) tend to block or disturb these natural dynamics. Careful design of capital investments and/or occasional sand nourishment would be important.

As compared to other countries as assessed with the VA methodology (IPCC, 1992, 1994), the NCCSAP-countries are different on one point. They show much less population at risk. They are comparable for the other aspects (capital value at risk, area at risk, wetlands at risk and protection costs (IPCC, 1992, 1994)). Most NCCSAP-countries have an underdeveloped coastal zone. This is contrary to the general pattern all over the world: highly occupied coastal zones. In this light, it is not advisable to treat the NCCSAP countries with the general strategies of the IPCC but to carefully assess the actual situation, prognoses and forthcoming needs.

Table 3.8 Vulnerability classes according to IPCC definitions (IPCC, 1991, 1994).

Impact category	Low	Medium	High	Critical
Population at risk (no/total)	<1%	1-10%	11-50%	>50%
Capital at risk (total loss/GNP)	<1%	1-3%	4-10%	>10%
Land at loss (area/total area)	<3%	3-10%	10-30%	>30%
Protection costs at risk (total costs/GNP)	<0.05%	0.05-0.25%	0.25-1%	>1%
Wetland at loss (area/total area)	<3%	3-10%	10-30%	>30%

Table 3.9 An overview of areas studied, climate scenarios and economic scenarios used, identified risks of SLR without adaptation and the adaptation costs. The last column 'Year' refers to the year in which most of the work on the study was completed.

Country	Area studied	Climate change scenarios	Economic scenarios	Year	People at risk without adaptation under scenarios studied*	Capital at risk without adaptation under scenarios studied*	Area at risk without adaptation under scenarios studied*	Adaptation measures considered	Protection costs under scenarios studied*
Bangladesh	Total country (divided in 9 vulnerability zones)	Null scenario, Moderate climate changes (30 cm, 2 degree temperature by 2100). Severe climate changes (100 cm, 4 degree temperature by year 2100).	business-as-usual 3,4% annual growth GDP up to 2010 high-development 5,7% annual growth GDP up to 2010	1994	About 40% of the population at risk of annual flooding in 2010 under severe climate change scenario.	Up to 12% of GNP annually in 2010 with 100 cm SLR scenario.	Up to 75 of land area is susceptible to annual flooding in 2010 with 100 cm SLR .		No estimates
Colombia	Pacific coast Atlantic coast Pilot areas	Null scenario 30 cm in 30 years 100 cm in 100 years	Optimistic 4.5% annual growth GDP 1.4% annual growth population Pessimistic 3.5% annual growth GDP 1.1% annual growth population	2003	± 2% (1.7 million persons) 0.21% (2030) 0.51% (2100)	Up to 4.5% of GDP (US$ 137 million) 0.2% (2030) 0.7% (2100)	± 7000 sq km will be lost due to 1 meter SLR	Protect Accommodate Retreat	From 3.4% of GDP in 2001 to 10% in 2100 (US$ 530 million in 2000 values)
Costa Rica	Pilot areas on the Pa-	Optimistic: 30 cm/100 yr		1999	Over 30,000 people (2%	No estimates	?		No estimates

Country	**Area studied**	**Climate change scenarios**	**Economic scenarios**	**Year**	**People at risk without adaptation under scenarios studied***	**Capital at risk without adaptation under scenarios studied***	**Area at risk without adaptation under scenarios studied***	**Adaptation measures considered**	**Protection costs under scenarios studied***
	cific coast	Pessimistic: 100 cm/100 yr			population)				
Ecuador	Country study Pilot areas	Null scenario, 30 cm in 100 years, 100 cm in 100 years	3% annual growth GNP 2.2% annual growth population	1998	7 to 12% in 2010 at risk annually	13 to 23% at risk annually in 2010	32 to 41% for one in hundred year flood	Total protection	US$ 2 to 4 billion (undiscounted)
Egypt	Mediterranean coast Red Sea coast Suez Canal Area coast	Null scenario 30 cm in 30 years 100 cm in 100 years	Business-as-usual (4.6% annual growth GNP - 2.5% annual growth population	1992	5.4 million people	Up to 14% of GNP	5,000 km^2 of land		5-10% of GNP
Ghana	Country study pilot areas	Null scenario ? 100 cm in X years	one socio-economic scenario, a defined response scenario and estimates of the associated cost.	1998	± 1% (132,000) people	No estimates	Two-third of the land area of the East Coast 0.5% of the country's land area		± US $ 590 million (1997 values)
Kazakh stan	Caspian Sea	Three sea levels of the Caspian Sea relative toe MSL minus 27 m minus 25 m minus 22 m	Not considered	1999	600,000 people (2% of the population of Kazakhstan)	No estimates	50 km inland on eastern coast of the Caspian sea for minus 22 m scenario	Protection plan; - Dike construction;; -Settlement relocation	± US $ 6.4 billion (undiscounted)
Nicaragua	Pacific coast Atlantic	Null scenario 100 cm in 100 years	?	1995	?	?	±6,000 km^2		No estimates

Coun-try	Area studied	Climate change sce-narios	Economic sce-narios	Year	People at risk without adapta-tion under sce-narios studied*	Capital at risk without adapta-tion under sce-narios studied*	Area at risk without adap-tation under scenarios stud-ied*	Adaptation measures con-sidered	Protection costs under scenarios stud-ied*
	coast								
Senegal	Two case study ar-eas	Null scenario Low: 7 cm in 2050 and up to 20 cm in 2100 Medium: 20 cm in 2050 and 50 cm in 2100 High: 40 cm in 2050 and 86 cm in 2100 Inundation levels	2 to 3% popula-tion growth rate 0.4% agricultural production growth rate 3% and 6% dis-count rates	1999	± 180,000 people (2% of the popu-lation) for 40 cm SLR in 2050 ± 1.6 million people (14% of the population) for 86 cm SLR in 2100	US$ 490 million in 2050 with a 3% Discount Rate	948 km^2 (0.5% of the total area of the country)	Protection	± US $ 250million (protection and replanting of dune areas) for 40 cm SLR in 2050 with a 3 percent discount rate
Suri-name	Country study Atlantic coast All river basins	Null scenario 30 cm in 30 years includ-ing 10% prec. incr.	5% annual growth of GNP up to 2025 1.2% annual in-crease in popula-tion	1999	±70.000 people (representing 11% of the na-tional popula-tion) will be at risk in the 30 cm scenario.	± US $240 mil-lion 11% of the annual GDP will be at risk in the 30 cm scenario.	± 4,000 km^2, es-pecially the capital is threat-ened (95% of the total area) .		± US $ 470 mil-lion (1999 val-ues).
Viet-nam	Country study Pilot areas	Null scenario 30 cm in 30 years 100 cm in 100 years	5-10% annual growth GDP up to 2025; difference be-tween mountain and coastal prov-inces	1996	± 17 million people due to annual flooding	± US$ 17 billion (80% of GNP) due to annual flooding In 30 years US$ 270 billion (125% of GNP)	± 1,750 km^2 (60% of Viet-nam's coastal wetlands).		± US $ 9 billion (40% of GNP) (undiscounted)
Yemen	One pilot area in-cluding Hodeidah	Null scenario 100 cm in 100 years		2000	± 91,000 people	±US$ 1.3 billion.	± 50 sq km		± US $ 20 mil-lion (1999 val-ues)

Country	Area studied	Climate change scenarios	Economic scenarios	Year	People at risk without adaptation under scenarios studied*	Capital at risk without adaptation under scenarios studied*	Area at risk without adaptation under scenarios studied*	Adaptation measures considered	Protection costs under scenarios studied*
	city								

* unless stated otherwise

3.5.3 Response strategies in general

The current section discusses the potential strategies for the countries studied. It will become clear that depending on the impact and country characteristics different strategies are advisable.

There are three basic types of response strategies: protect, accommodate and retreat. It is not in the scope of the VA method to perform a full cost-benefit analysis of all kinds of response options. The VA approach is therefore based on a simplified procedure, only considering the most straightforward options. E.g. a full protection strategy is often not realistic for most locations where measures should be taken, given the economic, social, cultural, legal and institutional circumstances in the countries. Table 3.9 presents the estimated adaptation costs for combinations of strategies (see also Sections 2.3, 2.4, 2.5 and 2.11). An indicative quick overview of potential response strategies for NCCSAP-countries in relation to the impacts is given in the next paragraphs.

Low overall impact

Some countries have large unoccupied coastal zones. Although the results suggest that such countries, e.g. Colombia, Costa Rica, Nicaragua, and Yemen, have a low overall vulnerability (taking the five aspects of Table 3.8), the vulnerability in specific locations (such as cities or other areas with high economic interests) can still be high to critical. A combined approach with (i) protection and careful future development planning in high economic interest areas and (ii) carefully planned accommodate and retreat measures in other high interest areas (such as nature reserves) seems the best option.

Critical relative impact, low absolute impact: retreat?

Some countries show high relative impact (expressed as a ratio of the entire country, Table 3.9). Expressed as part of the country's economical situation, the impact could be critical. Expressed in absolute figures the impact is less grave. Comparing absolute figures, SLR has low absolute impacts talking in absolute numbers of people or money. Here a careful study of the response strategy to use should be made before acting. Ghana and Suriname represent countries where protection measures are not the first to think about. In most cases, small amounts of people are at risk. Even retreating the major investments and big cities might be a good option given the small absolute amount of people and the small absolute contribution to GNP. It would be interesting to study how natural dynamics of the coast could attribute to the protection and make the coast more resilient. Combining both import of material (e.g. sand nourishment) and giving space to natural processes of erosion and accumulation (no hard construction in the coastal zone) might give protection in the long run without requiring major investments.

Critical impact but protection possible

For some countries, protection measures seem affordable. The cost-benefit ratio turns out profitable for protection measures. Senegal is such an example. A conservative estimate of the potential effect of SLR on the GNP shows a critical impact. A protection strategy would consist of sand-nourishment (use of natural processes and materials). Taking the relatively low costs of protection into account in relation to the high benefits, a strategy of protection seems a likely option.

Critical impact and high protection costs

Some countries are in a very critical position: the coastal zone offers a major contribution to the GNP and will seriously be affected by SLR. On the other hand, full protection measures would lead to a payback time of more than 1,000 years. The large investment costs for protection are not realistic in relation to the potential benefits. A strategy of accommodation and retreat seems the best option even though the societal impact is high. This seems still preferable over the high potential costs. The use of the natural dynamics of the coast in developing response strategies is recommended, also because this will be cheaper. We encounter a potential situation like this in Ecuador.

Critical impact and combined strategies

The most hazardous situation is in countries where the potential impact of SLR is critical and where large areas, large parts of the population (millions of people) and substantial capital values are at risk. Considering the large societal impact, retreat or accommodate can hardly be acceptable. Often it is even impossible to reallocate people and capital investments at such a scale. On the other hand, the costs of full protection also exceed any potential profit or yield of investments on such a large scale. The countries Bangladesh, Egypt and Vietnam represent this situation (Table 3.9). Large-scale protection, combined with accommodation and retreat seems both required and the only option, but these measures require huge financial resources.

3.5.4 Action plans defined in the VA

This section gives an overview of the action plans defined. For all countries, integrated coastal zone management (ICZM) should be seen as the best way of dealing with future problems. ICZM involves aspects in the institutional, organisational and legislative public administration and governance. Recommendations for specific engineering measures are rarely given. However, in some cases the need for engineering solutions (both hard measures such as groins and soft measures such as sand nourishment) is clearly demonstrated (for instance in the cases of Senegal, Vietnam, Egypt and Yemen). This is probably due to the level of detail of the studies. They are mostly carried out on a national scale and do not focus on solutions to the problems in a specific vulnerable area.

As a part of the country VA recommendations for the future, action plans were formulated in most of the VA studies. Table 3.11 presents an overview of actions mentioned in the action plans as seen during the years of study. The countries have not mentioned economic and financial aspects. It is clear that for all of the countries considered, extensive follow up activities are necessary in order to cope with the consequences of SLR.

In some cases, physical (engineering) solutions (both hard measures like groins and soft measures like sand nourishment) to cope with the expected problems are proposed. In almost all cases, additional research is recommended to gather more data and information before the implementation of specific solutions can start. In view of the character and scale of the VA studies (a first assessment, often on a nation-wide scale) this seems to be a sensible way of advancing towards sustainable and sound solutions to the problems most countries will face in the (near) future. In almost all cases, the introduction of integrated coastal zone management (ICZM) is taken as the most adequate way of dealing with future consequences of SLR. Adopting ICZM involves aspects in the institutional, organisational and legislative public administration and governance, such as (i) stakeholder analysis and participation; (ii) horizontal integration of disciplines (involving various disciplines and governance authorities); (iii) vertical integration (involving the various levels of government administration from national to municipal); (iv) awareness raising of the civilian population at risk (e.g. through local pilot projects). In many cases the present knowledge of the natural and the socio-economic coastal system is seen as being too limited. Data collection and management, education, training and transfer of tools are therefore often mentioned as important conditions for the successful introduction of ICZM.

3.5.5 Feasibility of implementation of action plans

The current section discusses the feasibility of implementation. Most countries will need substantial external funding for the implementation of response strategies.

Table 3.10 Feasibility of implementation of the action plans.

Country	VA LOI[1]	VA ECF[2]	VA TEC[3]	VA CSO[4]
Bangladesh	problem	Problem	partial problem	problem
Colombia	partial problem	Problem	partial problem	problem
Costa Rica	no problem	na[5]	no problem	na
Ecuador	partial problem	Problem	no problem	na
Egypt	partial problem	Problem	problem	no problem
Ghana	partial problem	Problem	partial problem	na
Kazakhstan	no problem	Problem	no problem	na
Nicaragua	problem	Problem	partial problem	partial problem
Senegal	partial problem	Problem	partial problem	partial problem
Suriname	partial problem	Problem	no problem	partial problem
Vietnam	problem	Problem	partial problem	partial problem
Yemen	partial problem	partial problem	problem	na

[1] VA LOI Legislative, institutional and organisational aspects
[2] VA ECF Economic and financial aspects
[3] VA TEC Technical aspects
[4] VA CSO Cultural and social aspects
[5] na Not analysed

Table 3.11 Overview of actions mentioned in the action plans for each country. Economic and financial aspects are not considered in this table (nm= not mentioned).

Countries **Actions mentioned in action-plans**	Ba	Co	CR	Ec	Eg	Gh	Ka	Ni	Se	Su	Vi	Ye
Legislative, institutional and organisational aspects												
Existence organisational structure												
Awareness raising at decision making level		x					x	x		x	x	x
Horizontal integration:	x	x										
high level ICZM co-ordination	x				x			x	x	x		
integrating ICZM co-ordination with regular departments	x	x									x	
co-ordination between departments		x			x				x			
(international) river basin management	x											
Operational level of structures												
Vertical integration:		x						x			x	
public participation	x							x		x		
legal instruments / enforcement					x			x		x		
ICZM plan/centre									x	x	x	x
integrating spatial planning with coastal planning					x							
platforms for negotiations of rights and needs	x											
Regulations nature conservation				x								
Pilot projects											x	
Capabilities of personnel												
Capacity building	x	x		x	x	x		x		x	x	x
Economic and financial aspects	nm	nm	nm	nm	nm	nm	nm	nm	nm	nm	nm	nm
Technical aspects												
Existence organisational structure												
(International) knowledge transfer	x											
Research on coastal processes		x		x	x	x	x	x	x		x	x
Operational level of structures												
Design criteria for coastal structures		x			x							
Capabilities of personnel												
Capacity building	x	x		x				x		x	x	
Organising data-collection		x		x		x	x	x		x	x	x
Infrastructures for:								x				
coastal protection							x	x		x		
Irrigation				x								

Countries **Actions mentioned in action-plans**	Ba	Co	CR	Ec	Eg	Gh	Ka	Ni	Se	Su	Vi	Ye
Drainage				x				x				
prevention of saline intrusion				x				x		x		
protection of investments							x					
Reallocation of infrastructures							x					
Cultural and social aspects												
Existence organisational structure												
Reallocation of population							x					
Operational level of structures												
Public participation	x							x		x		
Awareness raising		x						x		x	x	

Table 3.10 presents the feasibility of the action plans defined. For all four aspects of society (Table 3.11) a qualitative estimate is made on a gliding scale from no problem, partial problem to problem. Again the three levels of organisation were used A) Existence of basic structures; B) Performance/operational level; C) Capability of performers. The more problems are encountered at level A (Existence of basic structures) the less feasible is the action. Detailing, the evaluation classifications used are:

- *Problem*: this means that actions are not readily feasible, or not feasible without extensive (international) assistance. The existence of the basic organisational structures is not guaranteed. For the legislative structures this could e.g. mean extensive reorganisations. For economical aspects problematic could mean a requirement of extensive investments which are not readily available;
- *Partial problem*: the actions can be implemented. Problems occur more on the operational level. On a national scale initiatives can be implemented though on the local level problems will be encountered;
- *No problem*: problems are mainly at the capability level of the performers. Actions can be relatively easily implemented locally without or with little (international) assistance.

Note that some of the studies were carried out earlier than others (Table 3.9). Table 3.10 does therefore not represent the present situation for all cases. It can be concluded from Table 3.10 that economic and financial circumstances are a serious barrier to implement action plans and response strategies in all countries. This is due to the large negative impacts of SLR. Huge costs for adaptation and huge financial resources are needed.

Institutional, organisational or legislative circumstances are also often seen as an important barrier to implementation of response strategies (see also NCCSAP, 2000, Dorland et al., 2001). It can be concluded that only a few countries, i.e. Costa Rica, Kazakhstan, Ecuador, Egypt and to a minor extent Suriname, have an ICZM system that enables participation of all stakeholders (including the general public) (Table 3.10, NCCSAP, 2000, Dorland et al., 2001). The other countries seem to lack a co-ordinated ICZM. In several countries the centralised government and central planning systems were blocking the appropriate nesting of ICZM in all layers of public administration.

Technical aspects are also mentioned as (partially) problematic in several countries. These problems are mostly related to knowledge. Almost all countries need to organise data collection on the coastal system, going hand in hand with capacity building of local staff, and research on coastal processes (Table 3.10).

Cultural and social aspects are seen as the least problematic, although it should be noted that these aspects received less attention than the other aspects in most studies and hence need more detailed assessment. Cultural and social aspects include three levels. The first level deals with cultural and political stability in the country. Are there any ethnic or behavioural differences in the society that lead to unstable situations? The other aspects measured or dealing more with institutional aspects of being able to organise stakeholders. In this sense the first aspect is dealing more with the (cultural) interaction between people and the other two deal with the organisation of the interaction. A lack of sufficient stakeholder involvement was mentioned as one of the main problems in many countries, which is a serious barrier to implementation of ICZM. Colombia and Yemen also experience internal social conflicts that potentially block ICZM.

3.6 Adaptation and land use

Jan Verhagen[45] and Frits Mohren[46]

3.6.1 Agriculture

The methodology

Climate change and climate variability can substantially affect agricultural production and have a dramatic impact on local and national economies. Vulnerability of the agricultural sector to environmental change is however a complex issue. Most studies focused on the direct impact of climate change on crop production levels. Possible effects on farm management and socio-economic and socio-cultural structures were hardly considered. Isolating the effect of climate change on a complex system is not a trivial matter. The IVM/UNEP Handbook (Feenstra *et al*., 1998) provided to the teams, emphasises the importance of an integrated assessment. However, it did not provide the tools to perform this complex task.

Simulation models are not tools that can be used off the shelf. Understanding and working with complex dynamic simulation models and being able to understand and interpret the results requires not only understanding of the system that is modelled but also skills to evaluate whether the translation of the system behaviour to the model was done correctly. It is obvious that these requirements cannot be met in a short period. It does not matter whether one wants to use models for scientific (models to understand processes) purposes or engineering (models to assess system behaviour) approaches a basic understanding is required. In this the NCCSAP studies models are used in an exploratory manner, providing information on the direction of change and not so much on the exact magnitude of this change. The full range from detailed crop and livestock models to rating systems based on expert judgment was used.

For most countries crop yields are expected to decrease mainly as result of decreasing precipitation levels. Irrigation is an option in some cases but because the agricultural

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[45] See 5

[46] See 7

study was not linked to the water sector study the implications for the landscape and watershed were not assessed. Selection of new crops and adjustments in soil management were also identified as possible adaptation options.

In case where lack of data and experience with dynamic simulation models were limiting, an intermediate quantitative model/framework was proposed. This semi-quantitative approach makes use of both knowledge of basic phenological, physiological, morphological, and physical processes and expert judgment. It follows the logic of most dynamic crop simulation models but is based on a different level of detail. In this approach crop production is quantified using basic rules. Several production levels are defined. The analysis starts from a non-limiting production level (attainable production, determined only by crop characteristics, radiation and temperature), followed by the introduction of various yield-limiting and yield-reducing factors. The production levels are:

1. Potential production;
2. Yield reduction as a result of water stress;
3. Yield reduction because of lack of nutrients;
4. Yield reduction due to weed competition;
5. Yield reduction due to diseases;
6. Yield reduction as a result of pest incidence.

The first level is calculated using knowledge on crop phenology and growth rate under the prevailing environmental conditions, and requires information on incoming solar radiation and temperature. The subsequent levels of reduction are quantified based on literature and expert knowledge. The first reduction level (and to a lesser extent the second level) can be made spatially explicit using soil information. Other levels can be related to management, crop variety and climate.

This approach makes optimal use of both quantitative insights in the various processes and expert knowledge, and moreover it is in balance with the available data.

The effects of climate change are related to three components:

- Change in precipitation; quantity as well as spatial and temporal distribution;
- Changes in CO_2 level;
- Changes in temperature.

Production levels

The effects of changes in climate on production level can be estimated, using the same approach. Changes in precipitation will modify the magnitude of the yield reduction due to water stress, changes in CO_2-level will affect the growth rate, changes in temperature will influence the length of the phenological stages. When evaluating the impact not only the effects of each individual factor, but also possible interactions and feedback mechanisms should be considered.

Also adaptations to mitigate -possible- negative effects can be defined in terms relevant to the semi-quantitative approach: introduction of varieties with a different phenological pattern, use of fertiliser to optimise the efficiency of use of (scarce) water resources, etc.

Results

Some results of the individual country studies can be found in Chapter 2. In this section an overview of tools and methodologies is given.

Most studies aimed at linking food production to food security issues, so combining climate change with demographic development, technological options and socio-economic constrains.

Arable farming, both commercial and for local consumption were studied; only the Mongolian and Bolivian studies included livestock. When moving up from field to the farm and the regional scale it is in most countries imperative to include livestock. In Table 3.12 the range of crops is presented.

Table 3.12 Sectors included in the study.

Country	Arable crops	Grassland	Livestock
Costa Rica	+		
Bhutan	+		
Bolivia	+	+	+
Mali	+		
Senegal	+		
Yemen	+		

Table 3.13 Models used by the agricultural teams.

Crop	Costa Rica	Bhutan	Bolivia	Mali	Senegal	Yemen
Coffee	+					
Cotton				+		
Potato			+			+
Wheat	+					+
Rice		+			+	
Peanut					+	
Millet					+	
Maize					+	
Sorghum					+	
Dry bean			+			
Qat						+

All studies started with the intention to use crop growth simulation models to assess the impact of climate change on crop production. DSSAT was clearly the most favourite model; this model was also used in the United States Country Studies Program (USCSP). Experience with the use of DSSAT was not always readily available and alternative tools needed to be identified. For most situations locally or regionally developed models were available, in these cases the documentation and underlying principles of these models were examined by the consultant. The duration and nature of the programme did not allow for experimentation, model development or thorough testing of the models.

Table 3.14 Models used by the agricultural teams.

Model name	Bolivia	Bhuitan	Costa Rica	Senegal	Mali	Yemen
DSSAT	+	+	+			
SPUR	+					
COFEA			+			
ARABHY				+		
SARRA				+		
Cotton					+	
ALES						+
Semi-quantitative						+
Qualitative						+

The upscaling to the regional and national level was done in a qualitative manner. The link with other sectors such as water and forestry was done after completion of the individual studies by the national co-ordinator in co-operation with IVM. Most countries participating in the NCCSAP already participated in the USCSP and wanted to build on this earlier study. This however proved not always possible, as the expertise acquired during the USCSP was not directly available.

The process

Technical assistance worked in well-defined studies when procedures and methods are clear and a basic knowledge of methods and tools is available in the study team. In most of the studies it was clear that experience with modelling was rudimentary or lacking. Nevertheless most teams were very keen on using models. This process of learning by doing is rooted in the eagerness of the teams to work with models and keeping up with the latest methods and technologies. Obviously there is a tension between the thirst for new tools and knowledge and the programme that was designed to feed the National Communications.

Balancing the ambition levels of the teams and keeping the output objective of the studies in focus turned out to become a major task of the technical assistance. Including the technical expertise in the first phases of project definition and including training programs in the inception of the country studies overcame part of this problem.

Both the receiving and delivering end of the technical assistance had to find a modus operandi to work together. The on demand technical assistance was a new concept to most participants, roles and expectation patterns were not always clear. This was also fed by the levels of communication in the programme. The study teams worked not on stand alone projects but were part of multi-sectoral analysis which, in most countries, was co-ordinated by the ministry of environment. The study teams for agriculture and forestry would be part of the ministry of agriculture or agricultural universities.

The sector approach did not result in an integration of the various sectors, although clear links exist. Water and agriculture were discussed in isolation and adaptation options were sector based and limited to technological choices. Synergies and options at higher scales were not assessed. The current socio-economic context is essential in understanding food security and although the effects of climate change on socio-economic aspects of the agricultural system are difficult to assess this context is crucial in defining adaptation options that aim for food security.

Ambition levels of the teams were high and in most cases this had to be downscaled to safeguard the progress of the country studies. Training in the use of tools such as crop simulation models helped the teams in achieving part of the ambition levels. As the on demand assistance was new to most groups it took some time to get used to. Basically all problems could be solved via intensive communication and regular visits.

Most studies spent a large amount of time to determine the impacts of climate change on food and fibre production. After the selection of an important food or cash crop the studies narrowed down a simulation study of the effect of climate change on potential and water limited production levels. Although the studies yielded important and usable results the development and political context was lacking. Time and capacity was lacking to do an integral sector based vulnerability study. When the studies were conducted assessing the possible impacts of climate change was a very important signal to society and policy makers. The work done in the NCCSAP provided a sound basis for future work on climate change impacts and vulnerabilities.

3.6.2 Forestry

The first point that arises when comparing the two projects in Bolivia and Costa Rica is the difference in size of the countries. Since Bolivia is more than twenty times larger than Costa Rica, the resources and efforts needed to reach an equivalent level of reliable information is substantially different. This is reflected in the results, i.e. in general, a more detailed analysis was made in Costa Rica. Nevertheless, both countries have mobilised several researchers from different disciplines as required for climate change studies. Both countries applied methodologies approved by the IPCC (Intergovernmental Panel on Climate Change). The content of both studies is aimed at similar goals, despite the fact that the work was developed and integrated in different ways. Our contribution is focused on the forestry sector, but we also include a broader view of other areas of climate change impact analysis.

In the case of Bolivia, the forestry sector study contributed to three wider areas of analysis:

1. Emission Inventories of Greenhouse gases in Bolivia- 1994;
2. Evaluation of Mitigation options of Greenhouse gases effects;
3. Climate Scenarios analysis. Ecosystem Vulnerability to Climate Change.

In the case of Costa Rica the main contribution of the forestry sector study was focused on vulnerability of forests in Costa Rica to climate change. Nevertheless, this core study included several issues that were analysed and presented with more detail in other additional studies, presented as annexes. The number of different technical reports reflects the level of detail developed in the framework of the project.

A prime component of any climate change study is the description of the present climate and how this may change under certain future scenarios. A number of problems with this analysis arose in Bolivia due to the size and heterogeneity of the country. Global Circulation Model scenarios were used for this analysis for both Bolivia and Costa Rica. These models were tested against actual data from meteorological stations located in each country (6 in Costa Rica, and 32 in Bolivia). Different models were analysed and checked. Those provided by the Hadley Centre appeared to be the most suitable for both countries but others were tested as well. Once the GCM scenarios were calibrated and tested, their results were entered into the MAGICC model. This software allows the user to determine changes in greenhouse gas concentrations, global-mean surface air temperature and sea level resulting from anthropogenic emissions of greenhouse gases (Wigley, 2004).

The emission scenarios results generated by MAGICC were entered into the SCENGEN model. SCENGEN constructs a range of geographically explicit climate change scenarios for the world by exploiting the results from MAGICC and a set of GCM experiments, and combining these with observed global and regional climate data sets (Wigley, 2004). Three scenarios (optimistic, pessimistic and moderate) were developed for each country. For the purposes of the analysis, each country was divided into a number of geographical areas. Four areas were defined in Costa Rica, but only three were analysed. In Bolivia five areas were considered, but only four were analysed. Given the differences in the size of the two countries, it is evident that less detailed information is represented in the Bolivian analysis relative to that of Costa Rica.

Impact of climate change on forests

In order to relate climate change to changes of vegetation distribution , both the Bolivian and Costa Rican studies made use of Holdridge's System of Life Zones classification. This classification relates the potential presence of a given forest type to the level of rainfall, bio-temperature and of potential evaporation-transpiration. In other words it relates equilibrium vegetation type to climatic conditions. The idea behind its application is to give evidence of how new scenarios may indicate future environmental restrictions to the actual vegetation distribution. Additionally, other important variables can be added to improve the analysis. For example, Costa Rica added information on dry months and soils to get a more detailed description, and thus produce more detailed maps of potential vegetation cover-types.

The next step was to relate those maps to actual forest cover and to the presence of specific forest types, i.e. actual location, vegetation type and spreading. In the case of Costa Rica, field measurements were carried out in 68 sites to quantify carbon stocks in a given specific forest type, as well as to verify the forest type in each location. Although only primary forest was considered, this effort is very valuable because it introduces new data, obtained with a reliable methodology. The maps developed within the present study were based on a scale of resolution of 1:200,000, and were also compared with the maps produced by Bolaños and Watson (1993) with the same spatial resolution.

The spatial resolution of the vegetation maps generated in Bolivia is 1:10,000,000. This low resolution was imposed by the limited spatial resolution of the meteorological data. As data from meteorological stations were too scarce to cover the country, this information was not used to produce Holdridge's Life Forms distribution maps. Meteorological data, with a regular grid of 0.5º, provided by IIASA was used instead. The outputs of this model were compared with more detailed maps (1:1,000,000) elaborated between 1971 and 1975. These maps were somewhat supported with field verifications. The differences between maps probably results from the change of resolution. It is necessary, however, to obtain a better resolution and field verification in order to ensure that the actual representation of forests is feasible.

The Costa Rican study evaluated the vulnerability of Flora and Fauna based on the existence of their habitat. In Bolivia a gap model named GAP was applied to determine the effects of climate change on the production of tree species, which is interesting from an economic point of view. The limitation of this model application, as well as of other potentially applicable process-based models, is the availability of measured parameters needed to run such a model. Nevertheless, it is worthwhile to perform some specific analysis in areas were the information may be available. Complementary studies may also be helpful.

The contribution of the forestry sector to greenhouse gas emissions i.e. changes in land and forestry use, was also analysed in both countries using land use models and future land use scenarios. In Bolivia the model used was COPATH3. This model is based on spread-sheet calculations of changing areas of land cover types. In the case of Costa Rica several models like COPATH were checked. Finally a model of deforestation rates was used. This model considers different variables related to deforestation, including institutional, physical and socio-economical aspects.

3.7 National Communications

Michiel van Drunen[47]

3.7.1 Introduction

National Communications to the United Nations Framework Convention on Climate Change (UNFCCC) have become not only one of the central features of the Convention process and of the active involvement of these Parties therein, but they are also one of the most important tools for bringing climate change concerns to the attention of policy makers at the national level (UNFCCC, 2004).

Originally, the guidelines for preparing the National Communications were not very detailed. The National Communications Support Programme (NCSP) provided a four page ‘Tentative list of technical issues for consideration’ for non-Annex I parties, that was based on the results of the second Conference of Parties (COP) in 1996[48]. The scope of the National Communications according to these guidelines is summarised in Box 3.1. Most of the guidelines provided by the NCSP referred to the emission inventory (1 page) and the general description of steps (2 pages).

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47 See 1

48 Point 9 of the Ministrial Declaration states that The Ministers and other heads of delegations present at the second session of the Conference of the Parties to the United Nations Framework Convention on Climate Change ‘Welcome the efforts of developing country Parties to implement the Convention and thus to address climate change and its adverse impacts and, to this end, to make their initial national communications in accordance with guidelines adopted by the Conference of the Parties at its second session; and call on the GEF to provide expeditious and timely support to these Parties and initiate work towards a full replenishment in 1997.’

National communications and greenhouse gas inventories from Annex I Parties are subject to in-depth review by teams of independent experts. The aim is to provide a thorough technical assessment of each Party's commitments and steps taken towards their implementation. Periodic in-depth reviews of national communications started in 1995. They typically draw on findings from visits to the country concerned as well as desk-based studies. The guidelines of Box 3.1 were used by the reviewers hired by the NCSP to review the draft national communications.

Non-Annex I Parties have gained much experience in their first round of national communications. Building on this, the COP, at its eighth session, adopted a set of new and improved guidelines to help them prepare their second and, where appropriate, first and third national communications. In 2003 the UNFCCC issued its user manual for the guidelines on National Communications from Non-Annex I Parties (UNFCCC, 2004), which was obviously not applicable to the studies described here. Its main features are summarised in Section 4.4.

National communications were prepared as an integral part of, or in parallel to, the NCCSAP activities in Bolivia, Costa Rica, Ghana, Mongolia, Senegal and Yemen. In most cases, the results of the emission inventory and the vulnerability and adaptation studies were summarised in the National Communications.

Box 3.1 Scope of National Communications according to the 'Tentative list of technical issues for consideration' of the NC Support Programme.

The non-Annex I initial communications 'should include' three main components:
- Greenhouse gas inventory
- General description of steps
- Other information

Of these, the inventory is the key component and the only one for which non-Annex I Parties are required to follow explicit reporting guidelines. Technical assessment could therefore focus on the inventory.

Under general description of steps, various sub-components can be included because the COP Guidelines state that non-Annex I Parties 'should seek to include' these sub-components 'as appropriate'. The key sub-components are likely to be abatement, vulnerability, adaptation, and systematic observation. Because of the flexibility in the COP Guidelines, assessment of these sub-components could be optional. However, some non-Annex I Parties may choose to have these sub-components assessed if they are already included the national communications. An exception may be abatement, as countries are often sensitive about this issue.

Similarly, 'other information' may include a list of projects for financing. Again, the COP Guidelines state that this information can be provided on a 'voluntary basis', but many non-Annex I Parties may also wish to include this component in the assessment for the reasons stated above. The same would apply to 'Financial and technological needs' and constraints', which is also part of the COP Guidelines.

3.7.2 Bolivia

Bolivia published its First National Communication to the UNFCCC in 2000. The English version includes 138 pages. Besides the introduction and the executive summary it has five chapters: National circumstances (20 p.), National greenhouse gas inventory (17 p.), Vulnerability and adaptation (34 p.), Projections, plans and measures (30 p., including 14 pages with mitigation plans); and Systematic observation, education, and public awareness (17 p.).

Bolivia's NC is well illustrated and provides a good overview of the GHG emissions, the vulnerability towards climate change and Bolivia's climate change policies. The NCCSAP supported the studies for the GHG inventory and the V&A chapter.

The most important conclusions are:

- Activities related to land use change and forestry are the most important sources of GHG emissions with 38.6 million tons of CO_2, followed by the energy sector with 7.6 million tons of CO_2. The total GHG emissions amount 61.1 million tonnes CO_2 equivalents;
- Studies on vulnerability to climate change indicate that a probable 2° C temperature increase would not seriously damage cultivated areas if this increase goes together with precipitation increases. In the high plains, these conditions would be favourable for growing crops if provided with adaptation measures such as irrigation systems and improved cultural practices;
- Climate change in Bolivia affects human health directly and indirectly. The most frequent direct effects are: floods (Santa Cruz), landslides (La Paz), forest fires (Guarayos - Santa Cruz) and storms (Cochabamba), all of them increasing population mortality. Indirect effects include an increased occurrence of malaria and leishmaniasis;
- Cost effective mitigation measures mainly include energy efficiency measures in the energy and industry sectors and reforestation.

3.7.3 Costa Rica

Costa Rica's Initial National Communication (República de Costa Rica, 2000) is written in Spanish, but it includes an executive summary in English. The other chapters are National Circumstances (10 p.), Legislation (9 p.), Greenhouse gas emission inventory (17 p.), Climate change vulnerability (28 p.), Mitigation options (34 p.), Related programmes concerning sustainable development, systematic research, education, awareness raising and capacity building (6 p.), and Financial and technical assistance (2 p.).

The latter chapter indicates that Costa Rica explicitly uses its National Communication to find financial aid for new climate related projects. The NCCSAP contributed to the vulnerability and adaptation sections.

The main conclusions include:

- The main contributions to Costa Rica's GHG emissions come from the energy sector (4.3 million ton CO_2), industrial processes (0.4 million ton) and agriculture (0.15 million ton). Land use change has a net fixation of -0.9 million ton CO_2;
- Studies show that there are yield reductions in dry-land rice as precipitation decreases. High temperatures also provoke considerable yield drops. both potatoes and beans show an important decrease in yields with increasing temperature and precipitation variations. The effect of meteorological parameters on coffee yields is differential and depends on water availability during the crop cycle. Increased CO_2 concentrations will have a positive effect on all crops investigated;

- The three climate scenarios show that the tropical and montane life zones seem to diminish while they tend to increase in the premontane. Rain forest life zones diminish in all levels. Dry, moist and wet tropical forests diminish significantly. But premontane moist and wet forests as well as lower montane moist forests expand;
- Mitigation options were identified in the transport sector (railroads, integrated traffic systems), in the energy sector (renewables, energy conservation); in the industry sector (cement); and by reforestation and improved waste management.

3.7.4 Ghana

The Initial National Communication of Ghana (2001) includes the following chapters: Executive summary (17 p.), National circumstances (13 p.), Inventory of greenhouse gases (12 p.), Impacts, vulnerability and adaptation (36 p.), Measures contributing to addressing climate change (14 p.), Sustainable development and planning (12 p.), Research and systematic observation (9 p.), Education, training and public awareness (4 p.), International co-operation (2 p.), and Proposed climate change projects (42 p.).

Ghana, like Costa Rica, uses its National Communication to find financial aid for new climate related projects. The NCCSAP contributed to the vulnerability and adaptation sections. In addition, the NCCSAP management reviewed the draft version of the NC.

Its main conclusions are:

- Carbon sinks in forested and afforested lands offset the total CO_2 emissions thus making the country a net CO_2 remover (-0.4 million ton). Although the total methane emissions are lower than CO_2 emissions, the CO_2 equivalent emissions of CH_4 are about 2-3 times higher than the CO_2 emissions;
- The climate projections indicate that the average maximum temperature will increase by 2.5-3ºC in 2100. The mean annual rainfall would decrease by 170 mm in the Sudan Savannah Zone, 74 mm in the Guinea Savannah Zone and 99 mm in the Semi-Deciduous Rainforest Zone, respectively by the year 2100. In the High Rainforest Zone, however, the mean annual rainfall was projected to increase by 1105 mm by the year 2100;
- Using the climate scenarios, it was projected that the yield of maize would decrease in the Transition Zone from 0.5% in the year 2000 to 6.9% in the year 2020. The yield of millet however will not be affected by the projected climate change because millet is more drought tolerant;
- Simulations using projected climate change scenarios indicate reduction in flows between 30-40% for the year 2050 in all Ghana's river basins. Hydropower generation and irrigation are projected to be seriously affected;
- A preliminary assessment of the impacts of sea-level rise shows that about two-thirds of the total land area potentially at risk of flooding and shoreline recession lies within the East Coast. A total of 1,110 km^2 of land area may be lost as a consequence of a 1 m rise of sea level. The population at risk is estimated at 132,200;
- The loss of land by erosion and inundation will translate into loss of coastal habitats including important wetlands mostly in the Volta Delta. Increasing water depths and salinisation of lagoons as a result of sea-level rise will impact adversely on the feeding success of migratory and resident birds;

- Estimated cost of protecting all shorelines at risk with populations greater than 10% per km^2 with seawalls is US$1,144 million. The protection of important areas only reduces that cost to US$590 million;
- Cost effective mitigation measures include forest protection, replacement of biomass with LPG and gradual penetration of PV electricity and biogas.

3.7.5 Mongolia

The Initial National Communication of Mongolia (2001) includes seven chapters: National circumstances (11 p.), National greenhouse gas emissions (12 p.), Greenhouse gas mitigation issues (19 p.), Climate change, its impacts and adaptation measures (29 p.), Climate change response policy (10 p.), Research and systematic observation (3 p.), and Education, public awareness and international activity (4 p.). The NCCSAP contributed to the mitigation chapter and the impacts and adaptation sections on agriculture.

The main conclusions of Mongolia's National Communication are:

- Fossil fuel combustion is the largest source of CO_2 emissions in Mongolia, accounting for about 60% of all emissions. The second largest source is from the conversion of grasslands for cultivation (20-27%). The total emissions of CO_2 in Mongolia reached 9.1 million ton CO_2 in 1994;
- Cost effective mitigation options include Clean Coal Technology (effective dewatering systems, coal washing plants, selective mining and rock separation, briquetting technology); good housekeeping of electricity and heat production, energy management, steam-saving technology and dry processing of cement in the industry sector; and installation of thermostat radiator valves and balancing valves, improvement of building insulation, installation of efficient lighting in the residential and service sectors;
- A decrease in the high mountain and forest-steppe area and an increase in the steppe area is expected as a result of climate change. The desert area is projected to increase by 6.9-23.3% of the actual area by 2040 and by 10.7-25.5% by 2070. The findings of GCM scenarios show that water resources will tend to increase in the first quarter of the century and then decrease, returning close to current levels by 2050;
- The impact assessment indicated that temperature increase will have a negative impact on ewe weight gain (1-20 gram per day) in all geographical regions because the hot temperature at daytime will cause a reduction of grazing time;
- The potential wheat yield is expected to increase by 8-58% by 2040 and the potato yield by about 2-26%;
- The area of permafrost will be decreased significantly if warming trends continue. Accordingly, significant changes will take place in the surface water balance, the soil moisture and temperature regimes and the vegetation cover;
- Important adaptation measures include: development of rangeland and livestock management systems; improvement of forage production systems; use of modern pasture water supply systems; establishment of a risk management system; strengthening of the early warning system within the National Meteorological and Hydrological Services; irrigation; improvement of land cultivation management systems; set-up of legislative mechanisms for pasture use; and development of an insurance system for livestock and crops with respect to natural disasters.

3.7.6 Senegal

Already in 1997 the Initial National Communication of Senegal was published (République du Senegal, 1997), reflecting the country's sense of urgency regarding climate issues. In 1999 the NC was followed by a national strategy on climate change (République du Senegal, 1999.) The NC, which appeared in French only, includes seven chapters: National circumstances (21 p.), Greenhouse gas emission inventory (51 p.), Vulnerability studies (15 p.), Mitigation strategies (14 p.), The climate change training programme (2 p.) and Conclusions (2 p.). The NCCSAP contributed to the Vulnerability chapter (agriculture and coastal zones).

The main conclusions of Senegal's National Communication are:

- The total GHG emissions amounted 3.3 million tons CO_2 equivalents (0.4 ton / capita) in 1994. Land use change resulted in a net uptake of -6.0 million tons. Energy production, agriculture and waste contributed 3.8, 3.0 and 2.2 million tons CO_2 equivalents, respectively;
- The coastal zones of Senegal are vulnerable to sea level rise. Main effects include erosion, salt-water intrusion and mangrove degradation. If the sea level in 2100 has increased by 1 m, 6000 km^2 of coastal area are at risk, 109,000-178,000 people must move, 500-700 million dollars may be lost and coastal protection cost would amount 1 to 2 billion dollars;
- Without climate change, Senegal is able to feed its own population with moderate intensification of its agricultural practices and without endangering its natural resources in 2050. A dryer climate, however, would lower agricultural yields by 11 to 38%;
- Several GHG mitigation options are investigated including use of natural gas for electricity production and replacing LPG for firewood.

3.7.7 Yemen

Yemen's Initial National Communication was published in 2001 (Republic of Yemen, 2001). It includes seven chapters: Introduction (2 p.), National circumstances (21 p.), National greenhouse gas inventory (12 p.), Observation, research and impact of climate change (20 p.), Measures to reduce GHG emission and adaptation to climate change (14 p.), and Climate change research needs (4 p.). The NCCSAP contributed to the vulnerability and adaptation sections regarding agriculture and water resources. The main conclusions of Yemen's NC include:

- In 1995, Yemen emitted 18.7 million tons of CO_2 equivalents (1994 data were not available because of the civil war). Main contributors were the energy sector (10.1 million ton) and agriculture (6.3 million ton). Because in 1995 10.5 million ton of CO_2 was sequestered the net emission amounted 8.2 million ton CO_2 equivalents;
- Climate models and demand projections indicate a large deficit in the coverage of spate irrigation water. The demand varies between 551 and 595 million m^3/yr, while the available flow are only 105-127 million m^3/yr. Therefore, a sharp increase in groundwater use is foreseen, resulting in rapid depletion and salinisation of aquifers;

- All climate models project a decrease of potato and wheat yield. The decreases amount 6-33% depending on the region. An additional problem is that irrigation needs to be intensified;
- In the coastal area (Hodeidah city), potential losses amount 1.3 billion US$;
- Mitigation options include high efficiency combined cycle gas turbines, solar water heating, LPG stoves for fuelwood stoves and switching to natural gas and solar technologies;
- Adaptation options include improvement in water use efficiency, groundwater recharge and desalinisation; changing the crop yield subsidies, sustainable pest prevention programmes; and coastal protection measures for the Hodeidah city.

3.7.8 Synthesis

The National Communications of the countries considered here reflect their diversity. Availability of financial support, international assistance, data and national commitment determined the absolute and relative amount of information provided by the National Communications (Figure 3.1). Since the guidelines for NCs were only specific about the emission inventories, this chapter is the easiest to compare. Only Senegal provided much more information than required.

Costa Rica, Ghana and Yemen used their NCs to seek for financial support by including a list of climate projects. On average, 27 pages (22%) were spent on vulnerability and adaptation, whilst 18 (15%) pages were spent on mitigation (Figure 3.2). This suggests that the countries involved have used the National Communication to put the issues of mitigation and adaptation on the international agenda, and that they consider vulnerability and adaptation more important than mitigation. Considering the magnitude of the envisaged impacts of climate change in most developing countries it must be concluded that in the following version of the NCs even more attention should be given to the vulnerability and adaptation sections.

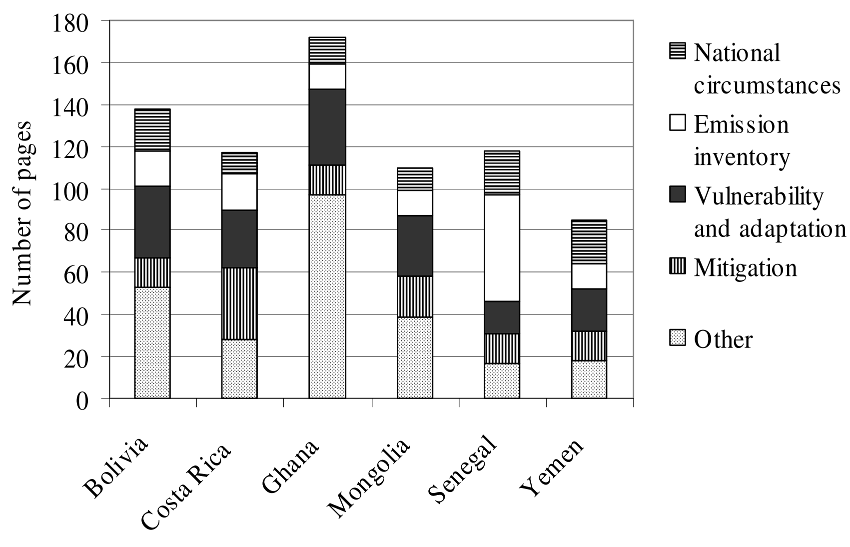

Figure 3.1 Number of pages in the National Communications devoted to the indicated chapters.

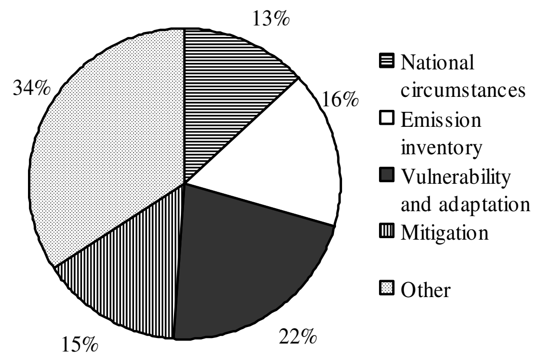

Figure 3.2 Average share of the indicated chapters in the National Communications.

4. Evaluation, lessons learned and outlook

4.1 Introduction

This chapter aims to put the results of the pre-NCCSAP and NCCSAP studies in a wider perspective: how can developing countries effectively deal with climate change in co-operation with developed countries or donor programmes. It discusses the methods used in the studies, it provides future outlooks and discusses the issues of awareness, capacity building and policy implementation.

The sections in this chapter are Mitigation assessment (Section 4.2), Adaptation assessments (Section 4.3), National Communications (Section 4.4) and Capacity building and Awareness raising (4.5). The chapter is concluded with a section with recommendations and conclusions (Section 4.6).

4.2 Mitigation assessment

Nico van der Linden[49] and Jan-Willem Martens[50]

4.2.1 Introduction

As part of the NCCSAP mitigation studies have been implemented with the objective to promote the further implementation of mitigation activities in Non-Annex I countries. As described in sections 1.4 and 3.3 such studies have been implemented in Bolivia, Mongolia, Yemen and Zimbabwe. The purpose of this section is to put these efforts into a wider perspective of GHG mitigation activities in developing countries.

The conclusions from these four countries are quite illustrative for the experience with mitigation policies in developing countries. While developing countries continue to grow their emissions, a switch to more GHG neutral technologies is not yet foreseen. It is highly unlikely that many climate friendly technologies would be developed in many developing countries due to unfavourable market conditions and the existence of significant market barriers. This has been recognised for example in the IPCC Special Report on Technology Transfer which mentions the slow progress in the development of many climate friendly technologies in Non-Annex I countries as a result of a number of policy, technical, financial, management, institutional and awareness barriers. For example, the key barriers for the development of renewable energy include a lack of technical expertise and weak institutional structures to plan, manage and maintain renewable energy programmes; the absence of clear policies and plans to guide renewable energy development; a lack of successful demonstration projects; a lack of the renewable energy resources potential; a lack of confidence in the technology by the policy makers; a lack of local of financial commitment and support to renewable energy; and continuing reliance on aid-funded projects. In fact, most initiatives regarding the development of renewable energy projects are either supported by ODA programmes or by the Global Environment

49 See 2
50 See 3

Facility (GEF). The GEF, through its implementing agencies World Bank, UNDP, UNEP and UNIDO has initiated a large number of projects and programmes in an attempt to reduce implementation costs and barriers to project development of renewable energy. This further demonstrates that commercialisation of climate friendly technologies in Non-Annex I countries will not occur without external assistance and the provision of financial incentives.

This process is confirmed if one looks to projections of the adoption of GHG neutral technologies in developing countries. As an example, the growth projections for the power sector (one of the largest GHG emitting sectors) are taken. Figure 4.1 shows the projections of energy sources used to generate power up to 2030 as produced by the World Energy Outlook. It is clear from this figure that the low GHG emitting technologies (nuclear, hydro and other renewables) have a constant share of around 15% in the total electricity generation in developing countries, while the majority of this 15% are provided by nuclear and hydro which have other environmental problems associated with them. Note that the largest contribution to lower GHG emissions is expected from a switch from oil to natural gas.

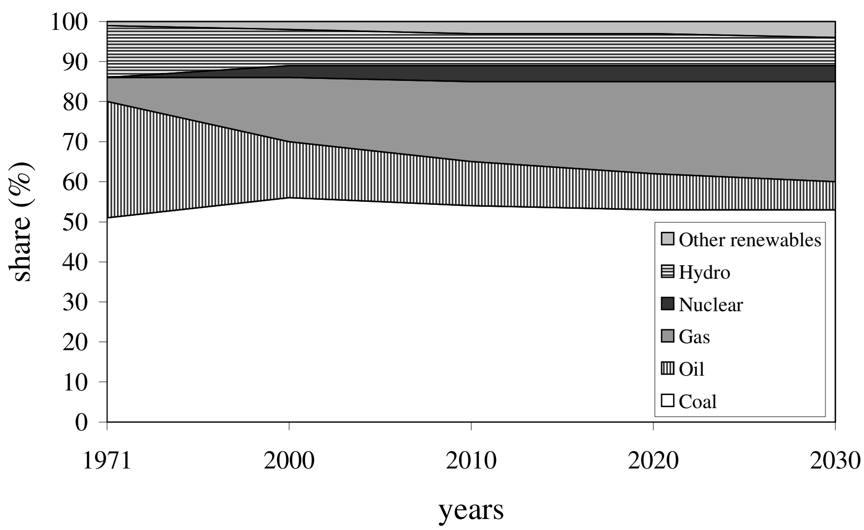

Figure 4.1 Energy sources for power generation for the next 30 years in Non-Annex I countries. Source: World Energy Outlook, 2003.

Despite the bleak outlook for mitigation activities there are a number of autonomous trends that will result in the relative reduction of GHG emissions.

- Energy efficiency measures across a wide diversity of industries. Especially in those countries where subsidies from energy are removed market parties will have an incentive to focus on energy efficiency;
- Fuel switch from oil and coal to natural gas in the power sector and transport (as is demonstrated in Figure 4.2);
- Niche applications for renewable energy where it can be competitive with conventional energy sources are:
  - The generation power with hydro power plants both large- and small-scale;

- Rural mini electricity grids powered by wind, solar, solar wind hybrids or wind diesel hybrids;
- Household energy technologies for rural households such as Solar Home Systems, improved cook stoves;
- Solar Water Heaters for urban households have been quite popular in countries such as Botswana, Nepal;
- Stand-alone power for remote telecommunication infrastructure;
- Cogeneration in sugar mills using bagasse residues;
- Wind energy in countries with supportive local policies such as in India.

Nevertheless, despite such positive trends, a majority of important GHG emissions in Non-Annex I Countries will not be addressed by them. Such activities include non-hydro renewable energy power projects, methane reduction of wastewater treatment and landfill gas extraction and reduction of industrial GHG such as N_2O, HFC-23, etc. This is a concern as developing countries emissions continue to grow and there is too little stimulus to create a structural shift towards low carbon economy, because indirect policies are less effective than direct policies since GHG emission reduction is not the target parameter of policy making.

4.2.2 Recent development with regard to CDM

Current status of CDM

Mid 2004, no CDM projects have passed the entire approval process until registration as an official CDM project. However, projects for which Project Design Documents (PDD) have been prepared, are denoted as 'CDM projects' in this section. Figure 4.2 shows an overview of the current mix of CDM projects.

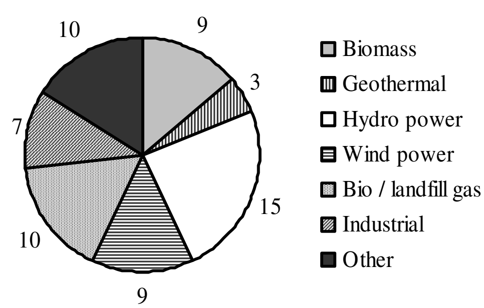

Figure 4.2 Number of CDM projects per technology category (not the total emission reductions *of the projects). Source: EcoSecurities CDM project database.*

Figure 4.2 clearly demonstrates that most CDM projects are renewable energy projects. At present, the share of renewable energy including 'bio/landfill gas' is 73%. Hydro power is the most dominant category CDM projects. Most projects reduce CO_2 emissions, except the projects in the bio/landfill gas category (16%), which reduce CH_4 emissions, and one project in the industrial sector, which reduces HFC-gases. Regarding the renewable energy mix, it is apparent that there are no solar energy projects and only a few geothermal energy projects (5%). In terms of share of emission reductions, landfill projects are very popular. Since landfill projects reduce methane emissions instead of carbon dioxide, the higher global warming potential result in a substantially higher share of emission reductions.

An interesting aspect is that contrary to the expectations, there are relatively few energy efficiency projects. One reason why this is not the case could be that a part of the energy efficiency projects is already financially feasible and does not need to be developed as CDM projects. Another explanation is that due to specific barriers for energy efficiency, the required internal rate of return for energy efficiency needs to be much higher than for power supply projects before implementation is considered.

Location of mitigation activities

Besides the most popular technologies among CDM projects, a second interesting characteristic of CDM projects is the project location. The success of a CDM project can be greatly influenced by the country in which it is located. Important country-specific CDM factors are:

- The intention of the government to ratify the Kyoto Protocol;
- Institutional organisation and willingness to endorse the transfer of Certified Emission Reductions (CERs);
- In case of electricity generation: the average amount of greenhouse gas emissions of the existing electricity park, which influences the amount of emission reductions a CDM project can generate.

Apart from the CDM specific factors, factors influencing the broader investment climate for mitigation activities are crucial. According to the IPCC Special Report on Technology Transfer the ‘enabling environment’ provided by the host county is very important determinant as a success factor for the implementation of mitigation activities. Elements of what constitutes an enabling environment are investment climate such as financial infrastructure, macroeconomic policies, but also more soft skills such as technical capabilities of the labour force, the presence of R&D and other innovation institutions in a country, etc.

Conclusion

Even though the current evidence is too little to have any scientific meaning, it appears that CDM supports the implementation of mitigation activities that otherwise would not likely to take off. Especially in the renewable energy sector and the waste management sector (landfill gas recovery and waste water treatment) private sector actors have jumped on the occasion to benefit from the CDM. Given the early stage of CDM and the lack of clarity in CDM procedures on the international policy level, this seems quite promising for the financing of mitigation activities in developing countries. As is to be expected mitigation activities are taking place in those countries that provide the best supportive environment for such activities.

4.2.3 Future developments with regard to CDM

The CDM is expected to become the most important financial source for climate mitigation activities in developing countries in the nearby future. The most important buyers of

CDM credits (or Certified Emission Reductions - CERs) will be the EU thanks to the emerging EU Emission Trading Scheme. As mentioned above, the demand for CERs comes from Annex I governments. On the other hand, the EU industries with an emission cap under the EU Emission Trading Scheme will also act as buyers of CERs. Although there are still many factors which may hamper the demand for CERs, Table 4.1 provides an estimate of possible demand for CERs.

Table 4.1 Demand for CERs up to 2012 Sources: Private communications with governments, Point Carbon - Carbon Market News (2004), Bygrave and Bosi (2004).

Governments	ton CO_2	€
Austria		70 mln
Canada		100 mln
Belgium		10 mln
Finland		10 mln
Italy	11Mt	55 mln
Spain	130Mt*	650 mln
The Netherlands	100Mt	500 mln
Japan Carbon Fund		46 mln
Subtotal		**1.4 bln**
Industries in the EU ETS		2 – 8 bln

* This figure was indicated by the previous Spanish government lead by the Popular Party. It is not clear if the new Spanish government lead by the Socialist party will continue that policy.

4.2.4 Long term perspectives on mitigation activities

One of the key lessons of the previous chapter is that the flexibility mechanisms of the Kyoto Protocol are the key driver for the implementation of mitigation activities in developing countries. The combined carrot and stick elements in the Kyoto Protocol (Binding commitments for Annex I parties and flexibility to sell carbon credits for projects in developing countries) provide the incentives for market players to engage at their own risk at mitigation activities. Despite the uncertainty of ratification of Kyoto and the long bureaucratic process to get CDM started, project developers have enthusiastically engaged in developing mitigation projects in Non-Annex I countries with the aim to eye to sell the carbon credits.

It is nevertheless important to recognise that there are still many steps to take before international carbon trading can provide the necessary drive to a structural reduction in global GHG emissions. The most important step for the international community to take is to reduce the current policy uncertainty. At the moment there is still a highly uncertain market environment with a lot of political risks unknown to other commodity markets. The uncertainty associated will ensure that major investments in GHG reducing technologies and large-scale dedication of R&D are still too risky. Mainstream market parties have not engaged themselves actively in the market (apart from a few global leaders) and follow the political developments in the carbon market from the sideline. The political uncertainty can be reduced to two elements. For one, it is not clear if there will be a long-term international climate policy rewarding structural reduction in GHG emissions. Besides, even if a long term policy carbon is adopted and a long term carbon trading framework is guaranteed, it is not clear if under such a policy ‘early action’ to reduce

GHG emissions will be rewarded[51]. Until such fundamental policy uncertainties are clarified, investing in GHG mitigation could be an investment with no return. Until they are clarified it is highly likely that major market players will consider a 'wait-and-see' approach as their best strategy.

The second Kyoto commitment period

In the first Kyoto commitment period (2008-2012) the historic emissions are the starting point for calculating the emissions ceilings. Countries have a reduction target relative to their 1990 emissions. The actual reduction targets are different per country and depend on domestic reduction opportunities and negotiating positions in Kyoto. The Kyoto ceilings range from -8% for the EU (as a whole) to +10% for Iceland. Developing countries do not have any targets.

Unfortunately, future commitments for a further mitigation of greenhouse gas emissions after Kyoto are still in a preliminary stage at the international climate change arena. In renegotiating ceilings an important issue will be whether developing countries will take up targets as well. Strict reduction targets that would harm economic growth will not be acceptable to developing countries and would not be fair considering the much higher per capita emissions of some developed countries. However, one of the reasons the US and Australian governments gave for not ratifying Kyoto was the fact that developing countries (more specifically China, India and Brazil) have no target at all. If developing countries take up a target (even if it would allow for growth of GHG emissions), this would help to reach political agreement. Some developing countries are already considering this. For example, in its domestic climate policy Malaysia is considering the fact that they will have to assume a ceiling under the second commitment period. Also, Chile and Argentina have indicated in the past to be favourable to the concept of adopting a binding commitment. However, until the Kyoto Protocol is entered into force and its operational framework is steady in place, no serious progress on negotiating a second commitment period is to be expected.

A framework for long term climate policy: contraction and convergence

Regardless of the progress in international commitments, there a number of approaches in literature providing a long-term framework for international GHG emission trading reduction aimed at a long-term reduction of greenhouse gases. Contraction and Convergence (C&C) is an idea that is promoted by the Global Commons Institute. The aims are to avoid global climate destabilisation and to do this in an equitable way.

The first part, *contraction*, starts with the assumption that there is a certain safe level of greenhouse gas in the atmosphere. If this level would be exceeded, the world would risk catastrophic effects of climate change. It is difficult to say what the safe level exactly is, but it is commonly agreed that CO_2 concentrations in the atmosphere should stay within

[51] To illustrate this point, take the European Emission Trading Scheme: Most national allocation plans for the first Period (2005 – 2007) are based on allocating historic emission for free (a principle called grandfathering). Since inefficient industries have relative more historic emissions compared to their more efficient competitors, they have been allocated more emission allowances. The efficient industries have thus been penalized for cutting their CO2 emissions prior to the ETS came into force.

the range of 450-550 parts per million by volume (ppmv). On the basis of this maximum concentration in the atmosphere, the maximum level of worldwide CO_2 emissions over time can be calculated.

To be realistic, this should take into account the current CO_2 emissions and also the growth path of emissions in the short term. In the longer term, there has to be a large contraction of emissions in order to stay within the safe level of (for example) 450 ppmv in the atmosphere. Based on the agreed upper limit of CO_2 concentration in the atmosphere combined with a feasible rate of emission reductions over time, a global emissions budget can be set.

The second part, *convergence,* is about an equitable distribution of the worldwide emissions budget. The ideal would be an equal per capita distribution of emission entitlements. This could be done per year, and distributed per country. The emission entitlements should then be tradable between individuals and/or between countries. Given population growth and the fact that emissions have to be reduced over time, the per capita entitlements will become less each year.

A sudden introduction of an equal per capita distribution of emission entitlements would not be politically acceptable. The current per capita emissions in developed countries are many times higher (especially in the USA) than those in developing countries. A trading system combined with a limit based on equal per capita emissions would involve huge transfers of money to developing countries.

Implication for global mitigation activities

An international Emission Trading Framework based on or similar to the Contraction & Convergence Framework has a number of benefits as a basis for international climate policy:

- By assigning property rights to all global GHG emissions and by providing binding commitments for all countries, it provides the backbone for a global long-term carbon market;
- Emission rights could be allocated at a national level, based on an equal per capita distribution worldwide and any activity reducing emissions will have a direct value. Hence, it would not matter if emissions are reduced via some national policy or a project. Any developing country reducing emissions in any way would be rewarded, because it can sell its allowances on the global carbon market;
- It provides market players with a long-term framework for assessing the development of GHG policy on basis of which they can make long-term investment decisions. The long term nature of the policy framework will send a clear price signal to market players allowing them to invest more in R&D of GHG reducing measures and in the application of more rigorous break-through technologies;
- A distribution of emission rights based on per capita emissions would result in developing countries receiving excess allowances that they can export to industrialised countries that are in need for additional allowances. This long term transfer of cash can provide the financing for long term investments in CO_2-neutral investments thus promoting a clean development path and avoid the polluting;

- A per capita distribution of emission rights at the national level would be equitable and also solve the problem of perverse incentives that currently exists under the CDM. The current interpretation of *additionality* is a disincentive for developing countries to develop decarbonising policies.

In CDM the concept of additionality means that a project is only considered additional if it reduces emissions compared to the situation without the CDM project, the baseline. This baseline also includes the legal requirements a country imposes. If climate-friendly sectoral policies and laws are put in place, projects are considered non-additional and are therefore excluded from the CDM. This provides Non-Annex I governments with a perverse incentive to refrain from introducing climate friendly legislation, in order to keep attracting investments via CDM.

With regard to mitigation activities, Figure 4.3 gives a picture of how the targets could be reached while continuing at business as usual economic growth. The thick line shows the business as usual emissions. By increasing efficiency the existing emissions growth trend could be reduced. The largest part of emission reductions will have to come from renewables. The graph also shows that in the process of adapting to low emission levels, emission allocations can be traded between developed and developing countries.

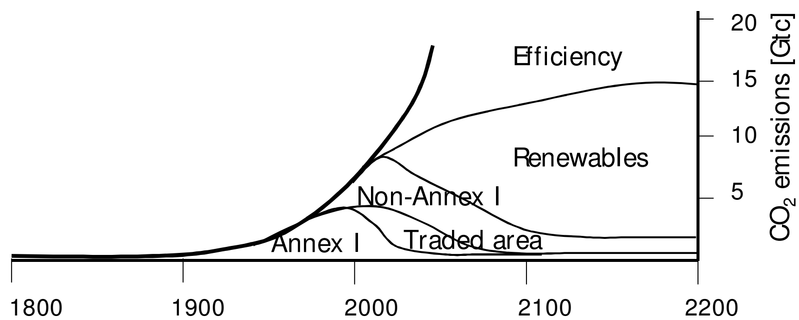

Figure 4.3 Share of renewables in the business as usual scenario (Source: http://www.gci.org.uk/).

4.3 Adaptation assessments

Marcel Rozemeijer[52], Arjan van der Weck[53], Frank van der Meulen[54], Rob Misdorp[55], Hans Leenen[56], Jan Verhagen[57], Frits Mohren[58] and Michiel van Drunen[59]

4.3.1 Coastal zones

As shown in Section 0, the country assessments gave insight in the degree of vulnerability of the country's coastal zones. Feasibility estimates indicated to which degree countries are able to develop response strategies to make them less vulnerable in the future. This section briefly discusses some general aspects that need to be taken into consideration when looking at future adaptation strategies. The aspects are connected to each other.

Awareness raising and stakeholder participation

So far, most results are only known to the experts who worked in the studies. To gain political support for planning and implementation of response strategies, a much wider stakeholders group needs to be involved. Two strategies to gain political support are:

- Linking adaptation measures for SLR to current economic and social interests;
- Linking the impacts of climate change to the daily livelihood of coastal communities and enable local stakeholders to claim ownership of the project results.

When adaptation measures have to be taken, it is important to identify the stakeholders that are associated with such activities. Who are they and do they see the measure as solving a particular problem and are they committed to co-operate in the action with other stakeholders? Such 'ownership is vital for effective planning and implementation of measures. In most cases, a change in behaviour of the stakeholders is desirable for effective coastal management. An example of a method to achieve such behavioural changes can be found in Olsen (2003).

Spatial planning

Planners are important stakeholders. In a larger perspective, effective coastal zone management is a matter of spatial planning. Hence, questions that must be addressed in assessments are: What are the planning scenarios for those areas that are at risk? If the use of natural dynamics of the coast is an option in dealing with the consequences of SLR, what are the plans for building hard obstacles and structures in the coastal zone? Impacts have been studied for periods up to 30-100 years. Furthermore, it is important that the planning focuses on no-regret solutions rather than on short-gain long regret-options (Delft Hydraulics, 2004).

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[52] See 8
[53] See 9
[54] See 43
[55] See 44
[56] See 39
[57] See 5
[58] See 7
[59] See 1

Case studies and 'work with nature'

Commitment and awareness are raised when communities see that measures are being planned and implemented that really improve their quality of life in the sense of safety, natural resources and socio-economy (Olsen, 2003). (Small) case studies could gain experience in this. It is proven good practice in coastal management that such projects develop best on community or small provincial level where the needs are/will be felt most strongly. Such projects need the support of higher governmental organisations (a vertical integration of decision layers), preferably under a national ICZM strategy. In low lying, vulnerable coastal areas there is a need for more detailed VA assessments and response strategies involving not only traditional hard engineering options, but also the 'soft' engineering options (e.g. sand nourishment). Making use of the natural dynamics of the coast ('working with nature') could present interesting response options. This has its consequences for spatial planning.

Integrated Coastal Zone Management

The present vulnerability of the coast will be increased by the impacts of climate change and SLR. Integrated Coastal Zone Management (ICZM) is seen as the most suitable approach to cope with the complexity of problems at the coast. Adaptation should be embedded in ICZM. It covers technical, political as well as institutional aspects. The establishment of a high level co-ordinating ICZM institution will favour this process. Box 4.1 provides an example of ICZM as an adaptive strategy.

Box 4.1 Vietnam as an example: a vulnerable coastal nation, practising VA and ICZM programs as adaptive strategies.

The coastal zone of Vietnam is critically vulnerable to Accelerated Sea Level Rise, while the financial coping capacity is relatively limited (Section 2.12). Among the 179 assessed coastal countries Vietnam ranked in the top class of coastal vulnerabilities. This was confirmed by the 'Vietnam Vulnerability Assessment' 1994-1997 (Hydrometerological Services, 1996), which concluded that ICZM was recognised by the Vietnam Government as an appropriate, adaptive strategy enhancing sustainable development of coastal resources. Between 1998-2000 preparations were made for a follow-up ICZM study in Vietnam. The CZM-Centre/RIKZ (Netherlands Ministry of Transport, Public Works and Water Management) with representatives of Vietnamese Ministry of Environment and the Netherlands Ministry of Foreign Affairs, prepared the Terms of Reference for an ICZM project in line with recommendations of UNCED - AGENDA 21 and 1992 Framework Convention on Climate Change. The main Vietnam Netherlands (VN)-ICZM project encompasses a period of 2000 – 2003. Vietnamese co-ordination is in the hands of the Ministry of Science, Technology and Environment and since 2003 by the Vietnamese Ministry of Natural Resources and Environment (MONRE). The ICZM expertise input is funded and co-ordinated by the Royal Netherlands Embassy in Hanoi and directed to Strategy and Action plans, data collection and management, awareness raising. The supporting Coastal Co-operation Program (CCP) is a co-operation between two Ministries: the Netherlands Ministry of Transport, Public Works and Water Management and the Vietnamese MONRE. It provides assistance in VN-ICZM institutional building at national level and support VN-ICZM awareness raising, monitoring, training, sustainable restoration at TTHue provincial level. At present, preparations are being made for the second phase of VN-ICZM and CCP starting in 2005. Some results of these two Vietnam - Netherlands ICZM efforts include:

1. Institutional strengthening: the simultaneous execution of the ICZM programs at the national level and in three coastal provinces resulted in a clear increase of vertical integration

through institutional strengthening, essential for an ICZM program. The high level national ICZM Committee is chaired by the Vice-Minister of MONRE and consists of Vice Governors (Vice-Chairmen of the Provincial People Committee) of the three ICZM pilot provinces and DGs of participating relevant Ministries. The legal mandate of this high level ICZM Committee is expanding, the input of NGOs and local stakeholders is debated, and the co-ordination of international funding for the implementation of ICZM based projects is strengthened. An ICZM Division recently created within MONRE, will ensure assistance in the planning and implementation of ICZM programs in future.

2. Horizontal integration takes shape through intensified co-operation and co-ordination between the relevant provincial Departments and Universities, local and international experts. The provincial ICZM Strategy Plans and Action Plans are prepared in a consultative way, using the integrated expertise.

3. Awareness raising: the VN-ICZM Newsletters are distributed among all Vietnamese coastal provinces. A Website linked to www.netcoast.nl provides overview of activities and coastal databases and several training courses on restoration and management of wetlands, on ICZM, on tools such as Remote Sensing and GIS were organised. Drawing competitions among 450 school children in were held in TTHue province. The 20 best drawings served as illustration for the for teachers: 'Where waters and land meet'. A series of ICZM consultative platform meetings at district or communal level aroused discussions on local problems and solutions among a wide audience mixing local, provincial and international expertise.

4. Monitoring programme: in TTHue province a monitoring programme was started on coastal dynamics, environmental quality and biodiversity, with a strategic policy document focussing on 'Why to monitor'. It included the expectations of the Provincial and District Leaders about dealing with overexploitation, pollution, and coastal erosion. The results of the first systematic monitoring campaigns show that increase of knowledge on the analysis of coastal processes is beneficial for decision-making on the sustainable development of near shore and lagoon resources.

5. From river to coast: some impacts of processes and interventions in the mountainous hinterland on the coastal zone in TTHue province were illustrated by STREAM, a GIS based water balance. The output of STREAM including impacts of climate change was used as input for the coastal, 3 D-lagoon modelling.

In conclusion: Ten years of ICZM efforts in Vietnam revealed that ICZM is indeed a useful mechanism addressing both the short term challenges related to population pressure as well as long term impacts of Climate Change. The results of the ICZM efforts in Vietnam were extensively discussed during provincial and national ICZM workshops. The results were reported and externally, internationally reviewed. The results were positively evaluated. The simultaneous introduction of ICZM at national level and in three pilot provinces was successful. Simultaneous execution of higher level of aggregated activities (strategy formulation) and lower level activities such as setting up monitoring programs, local platform discussions aiming at the preparation of bankable, problem solving projects is tedious but fruitful, and requires leaders with a well developed sense for overview. The introduction of ICZM requires a consistent and persistent attitude of the ICZM leading agencies as many conflicting interests are to be accommodated. Careful preparation takes time, in fact several years, as clearly demonstrated in Vietnam. The holistic approach of ICZM is appreciated in Vietnam and will further be introduced in the next set of the 29 low lying coastal provinces.

Outlook

The IPCC methodology has been used frequently, not only within the NCCSAP, but also in many other studies. It offers a generic framework comprising seven main steps of analysis, designed to be applicable to any natural and socio-economic system potentially affected by climate change. Klein *et al*. (1999) published a critique that focused specifically on Step 6 (assessment of autonomous adjustments) and Step 7 (evaluation of adaptation strategies). They describe experiences in The Netherlands, the United Kingdom and Japan, which more or less coincide with the experiences described above. They conclude that important missing elements include:

- The interaction between climate change and other pressures in determining impact potential;
- Public perception and awareness of climate change and its impacts;
- Spatial and temporal planning of adaptation measures;
- Mechanisms for public involvement;
- Non-technical (i.e., economic, legal, institutional) aspects of adaptation; and,
- Tools and procedures to evaluate adaptation performance.

Furthermore, Klein *et al.* (1999) regard coastal adaptation to climate change as a multi-stage and iterative process. Four basic steps recur in each of the case studies:

1. Information collection and awareness raising;
2. Planning and design;
3. Implementation; and
4. Monitoring and evaluation.

According to Klein *et al.* (1999) 'Assessing these elements in addition to the steps prescribed in the IPCC Technical Guidelines will give a more complete picture of a country's adaptive capacity and hence of the range of actions required to reduce its vulnerability. […] These actions are expected to be more than the implementation of technical options to retreat, accommodate or protect.'

As indicated in the coastal zone management studies described in this book, Geographical Information Systems (GIS) provide an essential tool. To support the 'multi-stage and iterative process' GIS and maps can be used as a negotiation tool to support water management (e.g. Janssen *et al.*, 2004). The idea is that stakeholder preferences are translated in spatially explicit maps. On the basis of these maps, proposed plans can be evaluated and potential conflicts can be identified.

Such activities can be placed within the broader context of what has been called Participatory GIS (PGIS). Participatory GIS has its roots in the 1990s when several social theorist authors started to express their concerns about the claimed objectivity and value-neutral nature of GIS (for an overview of the various authors and their arguments see Sheppard *et al.*, 1999 and Weiner *et al.*, 2002).

Specific questions that were addressed in this body of literature include how current models of geographical space have been developed in existing GIS, what cognitive and social understandings of geographical space may have been left out, how these lacunae have affected the utility of GIS for different groups or purposes, how can these lacunae be filled, how can communities be more involved, how does the use of GIS affect certain groups or individuals in society, does it lead to empowerment or marginalisation, etc.

As the PGIS research is still in its infancy, it is, at this moment, still difficult to draw some firm conclusions about the usefulness of Participatory GIS as an approach to climate change vulnerability assessment. Nevertheless it can be concluded that PGIS holds great potentials and it is very likely that it can stimulate the public debate and increase the involvement of people in the decision-making process.

4.3.2 Water resources

Evaluation

As indicated in Section 3.4, the experiences with the water resources varied from country to country. In all countries specific case study areas, or specific river basins were assessed. Therefore, no complete picture for the countries as a whole could be established. Generally the models were sufficient for the level of detail required. Also the data requirements were not too high.

Water resources are crucial for many sectors including agriculture, industry and electricity production. Therefore, an integrated, multidisciplinary approach is crucial for a comprehensive analysis and the formulation of effective adaptation options. In some of the studies, the co-operation with experts from different sectors appeared to be problematic.

A problem in some of the water resources studies that has been encountered is the lack of training in the programme, as some of the studies were not foreseen in the original project proposals. The training was given to technical committees only and on an ad-hoc basis. The need to make room for additional training in the project plans was expressed during the Amsterdam workshop (Dorland *et al*., 2001). This training should be multidisciplinary and open for specialists and non-specialists.

Outlook: water pricing

The Dublin Statement (1992) of the International Conference on Water and the Environment states ‘water has an economic value in all its competing uses and should be recognised as an economic good’. But internationally there is little agreement on what this actually means, either in theory or in practice. The interaction of three critical factors - the value of water, the use cost of water, and the opportunity costs of the resource - should be explored and assessed for different situations. The assessment of the relative magnitudes of ‘use costs’ and ‘opportunity costs’ shows that the implications of treating water as an economic resource vary quite widely depending on the sector.

Water scarcity does not only arise from lack of available resources, but often through uncontrolled and unsustainable use, or spilling of water. Potential adaptation measures in this case could be directed to control the use of water. The important challenge for urban water utilities in developing countries, is, therefore

- To reduce costs by more efficient operations (which increasingly means substantial involvement of the private sector);
- To raise tariffs (which typically cover less than one-third of costs).

A next step in the development of adaptation strategies for water resources problems could be to focus on the key issues of water scarcity. The potentials for improvement of existing situations and combating the anticipated worsening of those situations have not been exhaustively analysed. Water scarcity is a common problem, not just associated with climate change effects. It is very recognisable already, whereas the risk of flooding in areas that are not suffering from floods at the moment is a rather abstract concept. Thus a next step could be to investigate the potentials for water demand management by recognising water as an economic good. This is a rather sensitive but challenging concept and in some form or another it is well worth to open up a valuable discussion and be the start of potential adaptation strategies.

4.3.3 Agriculture and forestry

Climate change and climate variability can substantially affect agricultural production and may have a dramatic impact on local and national economies. Vulnerability of the agricultural sector to environmental change is, however, a complex issue. When addressing issues of food supply and food security, production levels alone are not the only issue but socio-economic mechanisms need to be addressed as well. Most studies focused on the direct impact of climate change on crop production levels at the farm level. Inclusion of possible effects on farm management and socio-economic and socio-cultural structures were not fully considered (Dorland *et al*., 2001).

Isolating the effects of climate change on complex systems is not a trivial matter. The UNEP/IVM Handbook (Feenstra *et al.*, 1998) provided to the teams emphasises the importance of an integrated assessment. It did, however, not provide the tools to perform this complex task. A stronger farming systems component linked to socio-economic studies would improve the impact and adaptation studies.

The NCCSAP clearly contributed to strengthening co-operation between different national institutes, but also established a south-south network. Two other objectives, bringing together expertise from various disciplines and producing an integrated assessment, were not always achieved. Linking technical and socio-economic studies requires a common integrated framework.

Outlook

Future work may focus on the evaluation of forest and agricultural land use policies and their effect on the vulnerability and emission profile of land use systems. Formulating development pathways taking into account changes in climate and climate variability is a way to have a more integrated approach of the climate change issue. Also in such an approach results from simulation models or semi quantitative models can be used to set priorities and reveal trade-offs between response strategies. The framework used so far does not stimulate radical changes in the design and operation of land use systems.

Issues such as bio products, bio fuels and carbon sequestration are currently not included in the agricultural studies. When moving from adaptation to mitigation these issues may emerge. This also holds for energy and water use efficiency in the agricultural production chain (Dorland *et al*., 2001).

4.4 National Communications

Michiel van Drunen[60]

4.4.1 Guidelines

As already indicated in Section 3.7.1, the 'guidelines' for writing National Communications for non-Annex I countries were very brief at the time the NCCSAP-I studies were running. The new guidelines that were set up in 2003 (UNFCCC, 2003) do not only describe the reporting requirements of emission inventories (9 pages), but also explicitly deal with adaptation (8 pages) and mitigation (5 pages). Since the methodologies of emission inventories and mitigation are relatively straightforward and well established, the focus will be on methodologies for vulnerability and adaptation (V&A). The Initial National Communications of the NCCSAP countries showed a wide variety of approaches and level of detail in the sections about V&A (see Section 3.7.8), partly because the assessment methodologies needed to be developed in parallel to the assessments themselves.

In the adaptation section of the new guidelines, the IVM/UNEP Handbook (Feenstra *et al.*, 1998) and the IPCC Seven Steps Method (Carter *et al.*, 1994) are explicitly mentioned in a footnote, as examples of 'appropriate methodise and guidelines […] for assessing vulnerability and adaptation to climate change'. These two have been discussed in detail in the Sections 1.5.2 and 1.5.3. It also refers to the UNDP Adaptation Policy Framework (APF) and the National Adaptation Programmes of Action (NAPA) guidelines. These two are summarised in the *Compendium on methods and tools to evaluate impacts of, vulnerability and adaptation to climate change* that is published on the UNFCCC website (UNFCCC, 2004a).

4.4.2 The UNDP Adaptation Policy Framework (APF)

The Adaptation Policy Framework (APF) aims 'to provide guidance to developing countries for formulating national policy options for adaptation to climate change. A major focus of the APF is to help countries integrate such adaptation policies into national and sectoral planning. It describes the key analytical concepts for developing adaptation strategies, policies and measures. The framework was initiated by UNDP in response to developing countries needs and builds upon the vulnerability and adaptation assessments conducted within the Initial National Communications of non-Annex I Parties' (UNDP, 2004).

The APF provides guidance on designing and implementing projects that reduce vulnerability to climate change, by both reducing potential negative impacts and enhancing any beneficial consequences of a changing climate. It seeks to integrate national policy making efforts with a 'bottom-up' movement. The framework emphasises five major principles:

- Adaptation policy and measures are assessed in a developmental context;

[60] See 1

- Adaptation to short-term climate variability and extreme events are explicitly included as a step toward reducing vulnerability to long-term change;
- Adaptation occurs at different levels in society, including the local level;
- The adaptation strategy and the process by which it is implemented are equally important; and
- Building adaptive capacity to cope with current climate is one way of preparing society to better cope with future climate.

The APF is a flexible approach in which the following five steps may be used in different combinations according to the amount of available in formation and the point of entry to the project (UNDP, 2004):

1. Defining project scope and design;
2. Assessing vulnerability under current climate;
3. Characterising future climate related risks;
4. Developing an adaptation strategy, and
5. Continuing the adaptation process.

The framework focuses on the involvement of stakeholders at all stages. The key tools include vulnerability mapping, dynamic simulation of sustainable livelihoods, multistakeholder analysis, cost benefit analysis, decision trees and multicriteria analysis (UNFCCC, 2004a).

4.4.3 The National Adaptation Programmes of Action (NAPA) Guidelines

NAPAs are mandated by the Conference of Parties to the UNFCCC for countries participating in the United Nations Least Developed Countries (LDC) Fund. This fund provides financial resources for the NAPAs. Countries are required to rank adaptation measures for funding based on such criteria as urgency and cost-effectiveness. The NAPA Guidelines are not in themselves a detailed framework for the assessment of vulnerability and adaptation. Instead, they provide some guidance for the process of compiling a document that specifies priority adaptation actions in the least developed countries (UNFCCC, 2004a).

The National Adaptation Programmes of Action (NAPA) Guidelines (Least Developed Countries Expert Group, 2002) provide some conceptual and procedural oversight for the process of producing a document that identifies national priorities for adaptation. The annotated guidelines address methodological approaches to identifying these priority activities.

The rationale behind it is that it is currently not possible to accurately predict climate change and its adverse effects, particularly at the local and regional levels. The IPCC maintains very strongly that learning to deal with climate *variability* and *extremes* is an excellent way of building adaptive capacity in the long run[61]. Strategies to cope with current climate variability and extremes exist at the community level. Hence one of the functions of the NAPA is to identify urgent action needed to expand the current coping range and enhance resilience in a way that would promote the capacity to adapt to current climate variability and extremes, and consequently to future climate change.

[61] This was also explicitly acknowledged by Hernán Moreano (Section 2.4.6).

The NAPA guidelines explicitly advocate the participation of men and women at the grassroots-level: 'First, they are able to provide information on current coping strategies that the NAPA seeks to enhance. Second, they will be affected the most by climatic impacts and hence will benefit the most from the actions prioritised in the NAPA' (Least Developed Countries Expert Group, 2002).

The guiding elements imply that the NAPA process should emphasise:

- A participatory approach involving stakeholders;
- A multidisciplinary approach;
- A complementary approach that builds on existing plans and programs;
- Sustainable development;
- Gender equity;
- A country driven approach;
- Sound environmental management;
- Cost-effectiveness;
- Simplicity, and
- Flexibility based on country specific circumstances.

In the NAPA process, much of the work of assessing vulnerability and adaptation is intended to be drawn from existing sources. The Guidelines do stress the importance of conducting a participatory assessment of vulnerability to current climate variability and extreme events as a starting point for assessing increased risk due to climate change. The key tools used in NAPAs are the same as in the APF (UNFCCC, 2004).

4.4.4 Discussion

Whereas the IPCC Technical Guidelines (Carter *et al*., 1994) and - to a lesser extent - the IVM/UNEP Handbook (Feenstra *et al*., 1998) represent examples of first generation approaches to the assessment of vulnerability and adaptation, the APF and the NAPA approaches are examples of second generation assessments that place the assessment of vulnerability at the centre of the process. Whilst the first-generation guidelines have an analytical thrust, and focus on an approach that emphasises the identification and quantification of impacts, the second-generation guidelines take the collection of possible adaptation options as the starting point of their analysis.

The main advantage of the first generation assessments is that they provide a straightforward methodology (see Figure 1.3). In addition, they provide a clear overview of the impacts of climate change for a specific sector or region. The problematic parts of the first generation assessment methods include the step from impact assessment to the formulation of adaptation options, evaluation and policy implementation. There are two reasons for this. First, apparently the technical experts are not able to effectively communicating the main results to the stakeholders. Second, the stakeholders (e.g. farmers, policymakers) are not involved in the first steps of the assessment, or have no specific interest in these steps, because these steps (scenarios development, modelling) are quite technical in nature. Therefore, the problems that the stakeholders encounter are not specifically dealt with during the studies. Thus the 'solutions' the studies offer are not necessarily appropriate solutions to the problems of the stakeholders.

Examples of these difficulties can be found in the sections about the studies in Bolivia (Section 2.2), Senegal (2.10) and Suriname (2.11) and to a lesser extent in Colombia (2.3), Ghana (2.6), Mali (2.8) and Vietnam (2.12). The programme co-ordinator in Bolivia, Oscar Paz, describes the challenges as follows: ‘It is evident that from the perspective of local response capacities, the results based on the use of simulation models must be complemented with studies and methodologies on the different institutional adjustments to face the impacts of the climate change […]. There have been proposals to continue with the studies made in this first stage, with the inclusion of the evaluation of local capacities and the extension of the geographic scenarios to validate and to complement the obtained data’ (Section 2.2.6).

In theory, the second-generation approaches could overcome the main disadvantages mentioned above. However, although the NAPA Guidelines outline some ‘guiding elements’, they fall short of providing a structured framework (UNFCCC, 2004a). For example, they do not provide a step-by-step methodology that can be applied by a team of sector specialists or a national climate study centre. The strong point of the NAPA approach is, the focus on the current capacity to deal with current extreme weather events. If vulnerable local communities are able to strengthen their capacity to deal with these events, they will probably also be better prepared for climate change.

In this respect, the APF is more practical for studies or projects like the ones described in this book. This framework is particularly applicable where the integration of adaptation measures into broader sector specific policies, economic development, poverty reduction objectives, or other policy domains is desirable. The challenge, however, is to integrate the ‘top-down’ approach, where national plans and policies need to be formulated based on climate and socio-economic scenarios, with the ‘bottom-up’ approach, where local communities participate in improving their adaptive capacities. See Section 4.6.4 for a more detailed discussion about this subject.

4.5 Capacity building and awareness raising

Ralph Lasage[62] and Michiel van Drunen[63]

4.5.1 Introduction

One of the goals of the NCCSAP was to increase knowledge on climate change in the partner countries and to raise awareness of the possible impacts of climate change. To assess if these goals were achieved and to learn from the experiences during the programme a questionnaire was sent to the involved researchers and policy makers. For both groups a questionnaire was formulated with a different scope in questions. For policymakers the emphasis was on the incorporation of research outcomes in policy and for researchers the emphasis was on the evaluation of capacity building. Twenty-four researchers and six coordinators / policymakers returned the questionnaire. First, the results of the questionnaires of the policymakers are listed and evaluated. Section 4.5.3

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[63] See 1

deals with the results of the researcher questionnaires. Section 4.5.4 presents the overall conclusions on the base of the questionnaires.

The respondents came from the following countries: Colombia, Ecuador, Kazakhstan, Mali, Mongolia, Senegal, Suriname and Zimbabwe.

4.5.2 Policy makers and coordinators

In total six of the country co-ordinators or other involved policymakers responded to the questionnaire sent by the NCCSAP management. Their reactions are summarised below.

All the policymakers that returned the questionnaire worked at government agencies or other governmental organisations. None of the reactions came from ministries.

Table 4.2 In what type of organisation are you employed?

I work for a:	*Respondents*
Government agency	2
Other governmental organisation	3
University	1

One of the respondents was a national focal point and country co-ordinator. Most respondents were country co-ordinators.

Table 4.3 What was your affiliation to the (pre-)NCCSAP phase I?

I was / am:	*Respondents*
National focal point co-ordinator to the UNFCCC	1
Country coordinator	4
Team leader	1
Other, please identify here, project coordinator	1

Did your involvement in the NCCSAP lead to an increase of your awareness on climate change issues? If yes, please describe in what way.

All the respondents increased their awareness on climate change issues. This increase was caused by the increase in knowledge on the overall field of climate change. Some learned how climate change scenarios work, others increased their knowledge on mitigation and adaptation options. Many respondents indicated they improved their knowledge on the impact of climate change on their country as a whole and on the vulnerability of certain areas, like the coastal zone and certain sectors like the economy, agriculture and ecosystems. The development of adaptation and mitigation strategies and the way to implement them gave insight in how they can deal with the effects of climate change. One respondent even worked on the preparation of a national action programme on climate change covering all the above.

Would you like to be involved in future climate change adaptation research activities?

The answer of all the respondents to this question is positive; they expect to gain more knowledge in future climate change related research. Climate change research is a very dynamic arena and many new insights are developed, the respondents want to keep up with these developments. Some indicate they need to continue projects, which started in the first phase of the NCCSAP. Most respondents became aware of vulnerable sectors or regions in their country and they want to study possible adaptive measures to meliorate the impacts of climate change. A remark made by two respondents is that knowledge on climate change needs to be shared with national and local authorities to meliorate the impacts, which was not realised in the first phase.

Could climate change adaptation research activities be made more useful for your country by linking the research directly with poverty alleviation, sustainable development, natural disasters or conflict and violence?

All the respondents considered the link to natural disasters important, because of the immediate effects on the community of a draught or a flooding.

Four respondents considered poverty alleviation as a good link, because the developing countries are more vulnerable to climate change impacts. When the country becomes more developed, it can improve its climate change policy and the population will become less vulnerable. Another respondent stated that a link with poverty alleviation would help to gain attention on climate change of institutions in the public sector.

Four respondents considered sustainable development as a good link in their country. For one this is because the country (Mali) lies in an arid and semi arid region. The stocks of natural resources, such as water, are very limited in comparison to the demands of the population. These resources need to be managed in a good and sustainable way. Another respondent states that sustainable development is the key focus of the government in his country; hence a link will increase the support for climate change research and policy.

Only one respondent chose the link to conflict or violence; in his country the limited resources, like pastures, water and agricultural land, are a source of conflict. Maybe with the development of an integral adaptation strategy, these conflicts can be contained.

Do you think it is useful if policy makers participate actively in the projects from the start?

Five respondents reacted positive and one negative. The main reasons to actively involve policy makers in the projects is that the respondents expect the project results will be used for making policy more quickly. One of them writes: 'They (policy makers) also need insight in the technical aspects. This will remove some barriers to successful implementation of the suggested options'. Another advantage is that the goals of the project will match the national development priorities; policy makers adopt the results of the project more quickly. Their involvement can also help to make the output of the project more action and policy oriented. The respondent that judged negative on the involvement of policy makers in the project uses the argument that policy makers should use the outcomes of the project. It seems he aims at the same goal as the other respondents, but in his opinion it is possible to realise it in another way.

Is climate change an important issue for your country?

All responded climate change is an important issue for their country, because of socio-economic vulnerability, the effects on resources (water and food), the effect on regions (coastal zone), the increase in variability and because of the location of the country (low lying, arid region).

The respondents find the approach as good to follow (4) and scientific of nature (5). They consider that the outcomes are convincing for policy makers (4) and that they are involved in the studies (4). The involvement of other groups (see table below) is less clear, half of the respondents answered the NGOs, experts and other relevant stakeholders were involved (3) the other half reacted negative on this part (2).

Table 4.4 What did you think of the approaches used in the NCCSAP?

The approach used in the NCCSAP …	*Yes*	*No*	*Remarks*
… was simple and straightforward	4	2	Easy to follow
… was too complicated	1	3	
… applicable	3	1	
… based on IPCC guidelines for GHG emissions	4		
… the UNEP/IVM Handbook on adaptation	5		
… the IPCC 7 steps method	1	2	Useful guide / not familiar with this
… revealed new information	3	1	About sea level rise
… was scientific in nature	5	1	A lot of research was done
… involved relevant policymakers	4	2	No, more scientific
… involved relevant NGOs	3	2	
… involved regional experts	3	2	
… involved other relevant stakeholders	3	2	
… convinced policymakers	4	1	It resulted in a national communication

Do you have interest to be involved in future activities?

All the respondents want to be involved in future activities, one of them keeps it clear and simple, he answers "of course". Out of the answers to the previous questions, it became clear the respondents thought projects were useful and that they learned form them. They want to increase their knowledge on climate change and especially on adaptation options. This is also the outcome of the answers on question 10 and 11 where they rate the importance of adaptation as high.

How do your rate the interest of your organisation in climate change adaptation?

All respondents (six) answered 'high'.

How do you rate the interest at the national policy level in climate change adaptation?

Five respondents answered 'high' and one 'medium'.

Almost all the respondents found it important that the ministries of environment, agriculture and waterworks are involved in adaptation policy design. One respondent chose all the ministries, which has a great impact because of the small amount of responses. If we consider this, the other ministries are not that important to be involved in adaptation policy design according to the respondents.

Table 4.5 Which ministries and other government organisations should be involved in climate change adaptation policy design?

Ministry	*Respondents*
Agriculture	5
Waterworks	5
Environment	5
Economic Affairs	4
Cabinet	2
External Affairs	2
Finance	2
Education	2
Social Affairs	2
Housing	2
Tourism	2
Internal Affairs	1

The NCCSAP and UNFCCC were highly valued. The IPCC less, but most value it above three. One respondent valued it low because the IPCC is not widely known in his country. Other donor funded research activities were valued less, but none of the respondents explained why.

Table 4.6 How do you rate the value of the NCCSAP and other programmes?

How do you rate the value…	*Average rate* *1 = insignificant - 5 = extremely valuable*
… of the UNFCCC for your country?	3.8
… of the IPCC assessment reports for your country?	3.6 (2-5)
… of the NCCSAP for your country?	4.2
… other donor funded research activities?	3.0

Have the NCCSAP and other donor funded projects been useful for adaptation policy design and implementation in your country?

One respondent gave a negative reaction on this question. In his country program adaptation was not studied in the project. According to the policymaker, it is urgently needed to start projects and programmes for the development of adaptation strategies in the second stage of the program. Other projects developed a national adaptation program and formulated adaptation strategies by use of the UNFCCC framework. In one country adaptation measures for the water infrastructure were developed. This program increased the public awareness on climate change and helped designing and implementing adaptation policy.

Do you have the impression that policymakers consider the results of NCCSAP ***biased*** *because the studies were financed by The Netherlands? Please explain.*

Two respondents had no opinion on this subject. Four did not think the results are biased. One of them wrote that ‘the results were considered as the work of the research team funded by the NCCSAP, not as a result of the NCCSAP’. All together, there is no indication that the results are considered biased.

Do you think the results of the project were useful for adaptation policy development and implementation?

Three respondents had no opinion on this subject. The other three were positive, because they prepared a national communication and an action programme, the outcomes of the projects are used by city planners and ecosystem managers, and because the outcomes can be used for the development of policy for water infrastructure.

Do you have other comments or suggestions for improving future donor activities?

The respondents have the following suggestions to improve future donor activities:

- Address pilot studies at community level to evaluate impacts on the development of the economy;
- It is desirable that the co-operation is continued in the future;
- It would be useful if the NCCSAP could be involved in the funding of new adaptation projects on the coastal zone;
- There is a need for a global framework to exchange knowledge on different policies, even though the initiatives should be locally driven. Through this framework, external support can be found and researchers can communicate with each other.

4.5.3 Researchers

In the NCCSAP over a hundred local researchers were involved. In total 24 researchers returned the questionnaires and their answers are summarised below.

Most respondents work for the government, thirteen in total. Only one of these works for a ministry, the others work at agencies or organisations. The university is also a big supplier of respondents; seven of the reactions came from people who work there. None of the involved consultants provided a questionnaire.

Table4.7 In what type of organisation are you employed?

Employer	*Respondents*
Ministry	1
Government agency	5
Other governmental organisation	7
University	7
Consultancy firm	-
Other NGO	1
Other, please identify here. ………	3

During the program, almost all the respondents increased their awareness on climate change issues, 21 reacted positive on this question and three negative. One of these three was involved in the IPCC before joining this program; the others were people with working experience on CC issues. The other respondents indicate they increased their knowledge on climate change issues; the table below lists the subjects they mentioned. The impact of CC is an important subject (7); one can consider this impact on a global scale (3) or on the country scale (5). All together 15 respondents mentioned it. An interesting remark is that one respondent now knows that many parts of climate change research are based on assumptions.

Table 4.8 Increase in awareness on climate change.

Technical	Got to learn impact of CC/CV (SLR, extremes)	7
	Impact CC on country	5
	Learned effect of CC on coastal zone management	3
	Global impact CC	3
	Development adaptation strategies	3
	Knowledge on climate scenario development	2
	Legal and institutional aspects of CC	1
	Development of GHG emission inventory	1
Communication	First time research on CC/CV	3
	Learned new research methods and approaches	2
	Raised awareness on CC	2
	Now know that many parts of CC research are based on assumptions	2
	Identified socio-economic factors that drive CC	1
No increase	Participated in IPCC since 1990	1

The respondents increased their capacity to assess climate change impact through many means. The table below lists their remarks and the number of time they were mentioned. The experience of working in a climate change project (8) is very important for increasing capacity; this includes working with specialist consultants (2), interaction with other institutions (1), multidisciplinary approach and the increased means to conduct vulnerability assessment (5). For one person this has lead to the ability to approach the CC problem from different viewpoints. The increase in knowledge on methodologies (6), technical background (6) and aspects of CC (3) are also important. Some of the respondents increased their capacity through the availability of data that was missing before (2).

Table 4.9 How has capacity to assess climate change impacts increased?

Technical / data	Improved knowledge on methodologies	6
	Increase in understanding of the aspects of CC	3
	More knowledge of the technical background (models, scenarios)	3
	Availability of information	2
	Increase in knowledge on influence CC on water resources	1
Communication / learning	Gained experience in assessing CC impacts, vulnerability and adaptation	8
	Increased means to conduct vulnerability assessment	5
	Working with specialist consultants from other countries	2
	Formulated national action program	1
Organisation / structure	The multidisciplinary approach of the studies	3
	Involvement of local authorities in the NCCSAP studies	2
	Interaction with other institutions in country	1
Other	Included adaptation in policy	1
	Visualization of CC problem from different points of view	1

Did the technical assistance provided in the NCCSAP satisfy your expectations?

In the opinion of the respondents the technical assistance contributed to the increase in the capacity to perform climate related research. Six found the technical assistance crucial, eleven very useful and six found it useful. No respondent found it almost or completely useless. For thirteen respondents the technical assistance satisfied their expectations and for ten it partly met their expectations. For more than half of the respondents (13) the technical assistance fully satisfied their expectations. For ten it partly met their expectations.

Some of the respondent only reaction is they learned a lot of the technical assistance (5), other are more precise and explain what they learned. Half of the respondents learned technical things like construction of CC scenarios (2), modelling (1) or had help acquiring technical information and data (2). The second part of the table below, under the line, lists negative experiences. Some of these are of organisational nature, communication (three in total) and how knowledge of the country is taken into account (1). These remarks are important to improve the co-operation and project structure for the follow up research.

Table 4.10 What were the experiences with technical assistance?

Experience	Respondents
Helped with development and practical construction of CC scenarios	3
Mathematical modelling of hydrological processes	1
Methodology guideline was very clear and applicable	2
Good when TA was in the country	3
Quality was excellent	2
Learned a lot of TA	5
Learned to work in a multinational team	1
Integrate research outcomes in policy development	1
Access to technological information and data	2
Some problems with financial assistance	1
Need to be more open to knowledge in the country	2
Need more communication in the beginning of the project	1
Expected more from TA, only one expert came	1
Communication over email did not work very well	2

The table below contains a list of topics on which the respondents would like to receive TA in future projects and how the TA can change in the future. The remarks are grouped under three themes, Communication, capacity building and organization / structure. The respondents gave many different remarks, the maximum score is three and many remarks are made only once. Ten respondents made a remark under capacity building; especially the placement of the technical expert in the country (3) and the placement of researchers in the Netherlands (3) are ways the respondents think will help to increase their capacity. Their ultimate goal is to be able to perform climate research themselves after the program has ended (2). Some plea for a greater involvement of local people and taking the goals of the country into account in the research. These remarks are listed under organization. Three respondents indicate they want to come into contact and work with other countries that experience the same effects of climate change as they. They want to share their knowledge and experiences and they hope to learn from the others.

Table 4.11 How to improve the technical assistance in the future?

Communication	Contact with other countries, visiting other groups with same subject	3
	Visit sites, have workshops and summer schools	1
	More constant and closer contact with TA	1
Capacity building	Organise workshops to share experience	3
	Technical expert in country (training)	3
	Place researchers in the Netherlands for a few weeks	2
	Communicate and transfer knowledge to the country so they can perform the research by themselves when the project ends	2
	Give more attention to training of national experts	1
Organisation / structure	Involve local coordinators in designing projects	2
	Give attention to continuity in cooperation	2
	Structured project guidelines	1
	More flexible approach in project design	1
	Base proposal on expert knowledge	1
	Work plan in beginning of project	1
	Involve stakeholders from the start	1
	More budget to do in depth research on aspects	1
	Use local expert (who know the area very well)	1
	Simplified financial procedure would improve TA	1
	Make room for country driven project objectives	1
	Pilot studies, to test adaptation options	1

More than two third of the respondents would like to receive assistance in vulnerability and adaptation methodologies (17). They also found climate scenario development important (14). Integrated risk management, which has a link with vulnerability and adaptation, is also an important subject they want to receive training in (12). The interest in research methods is medium, eight want to learn more about Geographical Information Systems (GIS) and eleven want to learn to conduct multidisciplinary research. Striking is the lack of interest in policy analysis, only three respondents mention this. One would expect this to be important to influence policy making.

Table 4.12 What kind of training or technical assistance would you like to receive in the future?

I would like to receive assistance/training in:	*Respondents*
Vulnerability and adaptation methodologies	17
Climate change scenario development	14
Integrated risk management	12
Multidisciplinary research	11
Geographical Information Systems	8
Socio-economic scenario development	8
Physical modelling	7
Policy plan design	6
Statistics	5
Project management	5
Policy analysis	4
Participatory processes	3
International law	2
Decision support / cost-benefit analysis	2
Financial administration	1

The table below lists the responses to the question on how to organise a TA in the future. Half of the respondents want to plan, organise and select the experts themselves (8) and the other half wants the donor to do this (7). The choice for an approach depends on the country. This choice needs to be discussed in the beginning of the project.

Table 4.13 How would you like to see technical assistance organised in future activities?

How do you prefer to organise TA?	*Respondents*
I want to select the experts providing TA myself	9
I want to plan and organise the TA myself	8
I want the donor to select the experts for me	7
I want the donor to plan and organise the TA	7
I want TA by experts from my own region	7
I want the TA from the best experts in the world	7

All the respondents were satisfied with the results of the projects; four researchers were even extremely satisfied. Some projects influenced policy making, such as the application of Integrated Coastal Zone Management (3), a National Communication and international negation tools for CC. But most projects were less influential and prepared the country for follow up activities. These projects identified gaps in knowledge, raised awareness on CC (stakeholder and policymakers) and made a first approach to study the impact of CC on their country.

Table 4.14 Are you satisfied with your results of the project?

Are you satisfied with your results of the project?	*Respondents*
Extremely satisfied	4
After the project there was an increase in the application of ICZM	3
Wrote a good report	2
Raised policy awareness on CC	2
Are satisfied, but there are new developments on CC, so need new research	2
Of course gave opportunity to show effect CC on coast	2
Evidence of information gaps, potential effects of CC and SLR is known to the country	1
Results form the sub region were the best, used also by policymakers	1
Identified gaps in local knowledge, which need to be filled	1
Work done was of good quality, is basis for future research	1
Raised stakeholder awareness on CC	1
1st National communication	1
International negotiation tools for CC	1
No follow-up, results were not communicated to local stakeholders	1

All but one respondent found the approach applicable (20). It was simple and straightforward according to fourteen of them. Five found it not simple and straightforward. Eighteen respondents thought the research was scientific and revealed new information (16). The NGOs were not involved enough. Half of the researchers think the projects convinced policymakers. Some respondents indicate they lack information and therefore cannot use the IPCC methods. There is a need to conduct more research before these methods are applicable in developing countries.

Table 4.15 What do you think of the approach applied for the studies in your country?

The approach I used	*Yes*	*No*	*N/A*
… was simple and straightforward	14	5	5
… was too complicated	4	12	8
… applicable	20	1	3
… based on IPCC guidelines for GHG emissions	11	4	9
… the UNEP/IVM Handbook on adaptation	8	3	13
… the IPCC 7 steps method	12	1	11
… revealed new information	16	2	6
… was scientific in nature	18	2	4
… involved relevant policymakers	11	4	9
… involved relevant NGOs	5	9	10
… involved regional experts	14	3	7
… involved other relevant stakeholders	12	2	10
… convinced policymakers	10	2	12

The teams were very engaged and worked well (8), the exchange of knowledge went well and within the project (4) and the teams were build up out of researchers and experts with different backgrounds (4). The negative remarks are below the line in the table. The problems seem to be project specific, but should to be considered in the follow up research program.

Table 4.16 Was the cooperation in the project team satisfactory?

Team satisfaction	*Respondents*
Good team and coordination, very engaged	8
Multidisciplinary investigators & experts	4
Exchange of knowledge and data within the project went very well	4
Capacity to direct research teams	1
Local coordinator quickly picked up the way to work	1
Cooperation was limited, but we wanted to	1
Qualified team	1
No experts, but supported by experts	1
Some problems with communication	1
The involved researchers had not enough knowledge on CC, which led to long discussions	1
Appointments not kept. Deadlines frequently exceeded.	1

The contribution to adaptation policy development consists largely of identification of vulnerable areas (7), the development of adaptive measures, such as the national action program (3), prevention of mudflows (2) and technical input (2) for policy such as the coastal zone management plan (3) and the costs of adaptation (1). A few projects have led to implementation of adaptive measures (2). In one country a climate change office was created as a result of the project. This will help to increase their capacity to deal with CC. Another respondent indicates that the project has led to an increase in capacity with the people who were involved.

Two respondents think there is still a lot to do on implementation of adaptation policy, especially on dissemination to policy makers and stakeholders. One respondent thinks the project was fit for the country as a whole, but not for regional or local policy makers. In following projects, attention should be given to the local stakeholders and policymakers. One respondent makes an important remark, he writes that the project was provocative; it made the people ask questions they had never asked before. This made them aware of climate change and its impacts.

Table 4.17 Are the results of the project useful for adaptation policy development and implementation?

Usefulness for adaptation policies and implementation	Respondents
Identification vulnerable areas for policy makers	7
Sufficient input for CZ management plan	3
Developed a national action program	3
Adaptation measures implemented	2
Identification of research needs	2
The research did a lot, however, there is room for further development and implementation of adaptation policy. Especially dissemination to policymakers and stakeholders of different economic sectors	2
Informed local policymakers the prevention of mudflows	2
Provided useful technical basis for policy.	2
Continuous awareness raising	2
First assessment of costs of adaptation	1
Capacity was build in national parties involved	1
Future planning CZ	1
Fit for national scale, not for regional and local scale	1
Need to investigate physical changes more	1
Creation of CC office in the country	1
The research was provocative, it made us ask questions we never had asked before	1
Contribution of financing	1

All the respondents want to work on future donor activities, because they learned a lot in the first phase and want to acquire more information (5). The Netherlands have a lot of are experience on adaptive strategies and the respondents want to profit from this (2), some indicate they are not up to do this kind of research by themselves (2). The information acquired in the projects provides policy makers with the technical background for their work (4). In these future projects, the respondents would like to work with neighboring countries (3) to learn from each other. These international contacts contribute to a broadening of the view of the researchers (1). Because of the dynamic nature of climate change and the continuous development of new insights, research needs to continue to keep up with the current state of knowledge (1).

Table 4.18 Would you be keen on working in future donor activities such as the NCCSAP?

Future activities	*Respondents*
Acquire a lot of knowledge (with the first phase)	5
Provide more information and scientific aspects for policy makers	4
Want to work with neighboring countries with same problems	3
Raise awareness	3
Could not do this kind of research by ourselves	2
More experience multidisciplinary groups	2
Benefit from Dutch knowledge (e.g. adaptation technology)	2
Suriname is threatened by CC, more information is needed	1
Many goals, help country in confronting SLR to coastal zone	1
Procedures are clear now, so future work will be quicker	1
The understanding of the natural phenomena, but also the benefit to the adaptation	1
Global and local environment is dynamic and research needs to be continuous	1
Development of international contacts and broadens one's view	1

Table 4.19 Do you have suggestions for improving the donor activities?

Suggestion	*Respondents*
Allocate funds for application of the research results into practice or implementation; finance adaptation projects, to increase the awareness to policymakers	3
Enhance technology transfer	1
Formulate a strategy to maintain in contact when the team has finished their project; the NCCSAP cooperation should be regular	2
Make sure there is follow up research which uses the collected data	1
Involve (local) experts at an early stage in the project	2
Technical assistance needs to be more structured with guiding documents	1
Take the priorities of the country into account and their scientific approach, in order to join efforts	1
Translate the NCCSAP documents into French	1
More attention to communication with stakeholders	1
Reduce the number of activity report that have to be written	1
Better quality control on the results used for national reports	1

4.5.4 Concluding remarks on the questionnaires

The results of the questionnaires lead to the following concluding remarks.

The co-ordinators and policymakers were very positive about the NCCSAP. They value the NCCSAP higher than other donor funded activities. They indicated that the (participation in the) NCCSAP studies increased their awareness on climate change studies. In the future they wish to connect climate change related projects to disaster preparedness programmes, and - to a lesser extent - to poverty alleviation and sustainable development programmes. They also want to involve policymakers in these projects, especially those from the ministries of agriculture, waterworks, environment and economic affairs.

The researchers usually worked at governmental institutions or universities. They were usually engaged in climate change impact assessment and they considered the methodologies applied suitable for the research questions they were addressing. They indicated that they increased their awareness and capacities about impact assessment methodologies, but also about vulnerability assessments, adaptation strategies and climate scenario development. The research was considered to be of good quality. Nevertheless they want to learn more about impact assessments and adaptation strategies, specifically in regional workshops and local training sessions. They were quite satisfied with the technical assistance provided in the NCCSAP, but they preferred to have been involved in the choice which technical consultant would assist them in future projects. The co-operation within the projects was usually good.

4.6 Recommendations

4.6.1 Objectives

As already mentioned in Section 1.2.1, the three main objectives in NCCSAP-I were:

- To enable developing countries to implement commitments under the Framework Convention on Climate Change;
- To create a greater awareness of climate change issues; and
- To increase the involvement of policy makers, scientists and the general public.

It can be concluded from the preceding chapters that in most countries these objectives were met to a large extent. This was also acknowledged by the evaluation that was commissioned by the Netherlands Ministry of Foreign Affairs (Blaas *et al.,* 2001). However, Blaas *et al.* also formulated two important critical remarks:

- The weakness in the adaptation studies where the focus was not on livelihood but on physical production;
- The inability of national ministries to take involvement significantly beyond their own stakeholder group and to raise greater awareness of the climate change issue particularly to the general public.

The latter remark was also formulated during the NCCSAP Workshop held in 2000 in Amsterdam (Dorland *et al.*, 2001). Here, one of the discussions specifically focused on the question: ‘how can the study results be successfully translated into policy plans?’. It became clear that this depends on the specific circumstances in the countries. Several requirements were, however, valid for most situations. These are elaborated in Section 4.6.2. The livelihood issue is addressed in Section 4.6.3.

4.6.2 Involvement

Policymakers need clear pictures. Therefore the study conclusions must give transparent information. Questions that have to be addressed include:

- Which scenarios are studied?
- What are the costs and benefits in these scenarios (e.g. of certain adaptation options)?
- Which stakeholders win and loose in these scenarios? How much do they win or loose?
- What is the relative meaning of the outcomes (e.g. in terms of share of GNP)?
- Which options have priority? Why?

- Who can contribute to the realisation of the plans (banks, international organisations, bilateral or multilateral programmes)?
- On what time scales do effects occur?
- Are there relevant secondary effects related to e.g. security, sustainability or health?

Policy actions must be taken by certain institutions. Often mitigation options must be addressed by the private sector and adaptation options by governmental institutions. Since governments are organised in sectors (e.g. water management, agriculture, environment, energy), it may be necessary to focus the study results towards steps to be taken in certain sectors. Such steps can then be included in the 'normal' sector policy plans. It should, however, be taken into account that measures in one sector do not interfere with effects in other sectors. For example, increased irrigation may not be feasible if the water resources are limited.

Furthermore, a single institution should be responsible for and take the lead in the implementation of the plans. It is important that such an institute is identified in the start-up phase of the studies. The study results will also be accepted sooner if the key stakeholders, such as the responsible institute, but also local stakeholders (e.g. farmers, energy companies or fisherman) are directly involved in the studies. Finally, funding plays an important role. Possible funding organisations should be involved in the earliest possible phase.

In several countries (e.g. Colombia, Ecuador), workshops were organised to inform local stakeholders and policymakers on climate change issues. This resulted in an increased awareness of the possible impacts of climate change and resulted in a higher priority being placed on the proposed action plans in the political agenda. If the general public is well informed, political pressure on politicians can enhance the attention paid to climate change issues in the political arena (Dorland *et al.*, 2001).

4.6.3 Livelihoods

Besides the issue of involvement, Blaas *et al.* (2001) raised the issue of livelihoods: 'In the impact and adaptation assessments, participants were largely from agronomy backgrounds and did not reflect local family farm production systems. In the coastal zone workshops emphasis was placed on physical infrastructure to combat sea level rise rather than the vulnerability of existing livelihoods.' And furthermore: 'The vulnerability and adaptation studies were driven by climate change modelling […]. Most importantly all models drove from impact of climate change to biophysical vulnerability, the basis of the vulnerability modelling. Little attention was paid to people - to vulnerability of livelihoods.'

With hindsight, it can be concluded that livelihoods played only a minor role for two reasons. First, the studies focused on impact assessment. At the time of the studies, many debates were still going on about the very existence of human induced climate change. Therefore, many studies were using the climate scenarios study outcomes to put the issue of climate change on the policy agenda. The precise effects on livelihoods were therefore considered of secondary importance.

Second, the methodologies to assess the influence of climate change on livelihoods were lacking. The existing methodologies were very much top-down approaches that started with climate scenarios and socio-economic scenarios and although they recommended involving relevant stakeholders, the researchers concerned (climate specialists, sector specialists) were usually not equipped with the skills and tools to effectively put this into practice.

4.6.4 A suitable framework

The Amsterdam Workshop (Dorland *et al.*, 2001) made clear that policy implementation was not included in the methods that were used in the NCCSAP studies. However, the Amsterdam Workshop did not provide a comprehensive framework either. It was also shown that the studies usually took a top-down approach where livelihoods played only a minor role.

Probably the Adaptation Policy Framework (UNDP, 2004) provides a framework that can narrow the gap between the study projects and policy implementation. Furthermore it addresses the issue of livelihoods, although the term is usually mentioned in the context of local stakeholder involvement in the APF framework. Existing tools (such as multicriteria analysis and cost benefit analysis) and newly developed tools (such as participatory geographical information systems) would be particularly useful in this respect.

This does not necessarily mean that the first-generation approaches are already obsolete. To prepare for climate change at least the two following issues must be addressed. The first issue concerns the national and international policy agenda. Climate change affects many sectors and policy fields. Obvious examples include energy, agriculture, water resources and coastal defence. In all policy decisions made in these sectors and fields, the impacts of climate change should be taken into account[64]. The first-generation approaches provide excellent toolkits to assess these impacts, in terms of sea level rise, temperature changes, changes in rainfall patterns, and subsequent effects in the sectors such as occurrence of floodings, crop yield changes and electricity demand.

Furthermore, the first-generation approaches provide results on relatively large geographical scale, such as a country's coastal zone, a river basin or a province. Typically, second-generation approaches consider local communities as it is expected that adaptation needs to be taken care of also at this level. Since it is impossible to gather climate change vulnerability information from e.g. all communities in a country within a reasonable time, the first-generation approaches need to be applied to obtain countrywide data.

The second issue concerns the livelihoods of people and local communities. Communities that are likely to be affected by climate change must be made aware of the risks and they must be prepared to deal with climate change impacts. It was shown in several cases that if communities are resilient enough to deal with present extreme weather events, they also have enough adaptive capacity to deal with future climate change, supposing that their socio-economic circumstances do not deteriorate too much. Therefore, strengthening the capacities of local communities to deal with extreme events is probably the key to be prepared for the impacts of climate change.

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[64] The term used for this is 'mainstreaming'; see Huq *et al.* (2003) and Bouwer *et al.* (2004) for more information.

Thus, it can be concluded that first-generation and second-generation approaches both have distinct objectives and outputs. Therefore they can peacefully co-exist, depending on the questions that need to be addressed. Moreover, both approaches can provide added value for each other. For instance, the climate scenarios and socio-economic scenarios can be included in the vulnerability assessment of a local community. Also, local information about adaptive capacity can provide valuable information for assessing the regional impacts of e.g. floods.

It should be noted that the second-generation frameworks require different specialists. Whilst in the first-generation frameworks mainly climate specialists and technical sector specialists were working, in the second-generation framework not only local specialists and other stakeholders should be involved, but also social scientists such as economists and policy experts.

4.6.5 Conclusions

The pre-NCCSAP and NCCSAP study programmes were successful in the following fields:

- Results. The country studies revealed important and relevant results that were generally considered scientifically based;
- Approaches. The rationale of the programmes was that researchers in the countries carried out the studies with (remote) assistance of technical experts. This approach appears to have worked very well in most countries. The IPCC Seven Steps and IVM/UNEP methodologies were applicable and useful in most countries;
- Capacity building. The researchers indicated that they increased their awareness and capacities about impact assessment methodologies, but also about vulnerability assessments, adaptation strategies and climate scenario development. However, it seems that in most countries neither a significant part of the policymakers nor a significant part of the general public has become more aware of climate change issues as a result of the (pre)NCCSAP study results.

The Clean Development Mechanism is expected to become the most important financial source for climate mitigation activities in developing countries in the *nearby* future. Policy uncertainty is however the largest barrier for CDM projects.

New approaches for assessing vulnerability and for formulating and implementing adaptation options are required. UNEP's Adaptation Policy Framework could provide a framework for projects in these fields. However, the first-generation approaches are still needed, especially for assessing potential climate change impacts on relatively large geographical scales.

The challenge is to combine regional first-generation projects with local second generation projects on similar subjects. A good approach would be to run such projects in parallel and to organise common workshops that stimulate the researchers of both project to cross-fertilise each others work.

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